

NEWS



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NEWS CONFERENCE

RESULTS FROM APOLLO 12 LUNAR SURFACE EXPERIMENTS

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11/20/70

McLaughlin  
CR 13138

ALLAWAY: I think we should get going. We have available handout statements, summary statements, the background statements, on each of the experiments that will be talked about, and also one on the operation of the ALSEP.

We will make a transcript of this news conference. It will be ready early next week I think, and if you are not on our regular mailing list you can address an envelope to yourselves in the back of the room and leave it.

We have a pretty tight-packed program this morning, with a number of people to be heard, and some live data displays. Our plan is to go through the succession of speakers and have a question period afterwards in which all the speakers will be assembled on the stage.

With that I would like to turn the program over to Dr. Rocco Petrone who is the Apollo Program Director.

PETRONE: Good morning, gentlemen.

At 9:21 Eastern Standard Time today the ALSEP deployed on the moon by the crew of Apollo 12 started its 365th day of operation. We have with us today to explain the information we have been getting back over this past year the principal investigators of the experiments which flew on Apollo 12.

Dr. Latham will cover the passive seismic experiment. Dr. Freeman will cover the suprathreshold ion detector, Dr. Snyder the solar wind spectrometer. Dr. Swann will give us a resume of the field geology investigation, and Dr. Sonett interpretation of the lunar surface magnetometer.

We will not cover this morning the cold cathode gauge which Dr. Johnson was the principal investigator for. As you know and may remember, that failed about a day, 14 hours, after we deployed it. We have that planned to fly on later missions, and we feel by testing it on the ground we have come to understand some of the electronic circuitry better and have made changes and will fly the cold cathode gauge on later missions. We

not have a resume of that today.

We also have here today Alan Bean who is going to briefly discuss with you the deployment of the ALSEP and the situation he was confronted with in terms of laying this out and following the desires of the principal investigators to make sure the instruments were handled a certain way and placed in their positions a certain way to be certain the information we got back was going to be interpretable.

And we have asked Dr. Frank Press then at the end of this to summarize and to give you the interrelationship of the data we are getting from the various instruments, and Dr. Press will bring into focus the various findings.

Remember now this is just one ALSEP and findings in one area. And it's on that basis that Dr. Press will make his summary.

ALSEP's first anniversary is certainly both a scientific and a technological triumph. The design specification was for one lunar day and night. Our design goal was for one calendar year. As of today we have met that goal. We certainly hope that the instruments, the radiothermal generator, the power source, the experiments will continue to function over a much longer period of time.

Needless to say, a year ago, as we looked at the time ahead of us, a year seemed a long time, and a year is a long time, and yet I am sure we'd like to have this work many more months and many more years if we can.

The ALSEP central station, which will be described to you later this morning, just briefly has received and processed over 6,500 commands in this past year. Some of the commands will just be described briefly here this morning, but the station isn't just sitting there as an inert mass. It's a dynamic remote station. It's an automated station which man has placed on the moon, now operated remotely 24 hours a day, 7-day week. We are receiving data from this station.

As I mentioned, we have given and executed 6,500

commands over the last year. The real time -- and this is written up in a handout -- we are up approximately 2 hours a day during the daytime -- that is, 14 days when the sun is up -- and about an hour every other day during the nighttime.

We do cover continuously during terminator passings. This is when you see the greatest changes in the data we are reading.

I think I'd like to point out that this automated station now working on the moon is working in extremely high vacuum, and it has undergone 2,600 swings of temperature of approximately 500 degrees. This is equivalent, say on earth, to taking our instruments from the Sahara Desert to the Antarctic say in wintertime and back some 26 times, or 13 times for the whole trip. And this is certainly an environment much greater in terms of demand than we have placed on any other instruments we put in space.

I think with that much of an introduction and the description of what we have, we would now like to go into the program, and I'd like to introduce Captain Alan Bean to start off with his resume for you of his experiences with ALSEP just one year ago.

BEAN: I think, in light of what the Russians have been doing the last few days, it might be interesting, instead of talking about what we did a year ago, since we have had a chance to discuss that a couple of times since we got back, to try to imagine what we did that maybe you couldn't do with a vehicle like the Russians have got up there right now or the problems that you might experience if you were trying to do this sort of a deployment in an unmanned mode.

First of all, the equipment that we laid out on the moon, the ALSEP, weighed about 300 pounds. So you'd have to ask yourself if you can get that sort of gear on top of a Rover and run it around and put it in the right place -- at least one like we see the Russians have today.

I guess the next thing you'd have to ask yourself

is how would the sequence of events go as you did it?

Well, our procedures were to come down, do a few experiments beforehand, then go back and offload the ALSEP. I guess if you had an unmanned vehicle you could go ahead and have the equipment loaded on the top of it. Whether you could do the 300 pounds is a good question.

Next thing you might do-- We had to go back and take the fuel element, the plutonium-238, out of the cast that we had it in because we couldn't put it in the generator because it would have gotten too hot in that particular configuration. We would have liked to have flown it that way and then we wouldn't have had to do this job.

Let's suppose perhaps if you had an unmanned vehicle you might have the same sort of situation, in that you might not be able to put the element in the generator itself. As you recall, when we were on the moon and got ready to remove the element, put it in the generator, we were unable to do it because there were some mechanical interferences. I was pulling on the extraction device. Pete Conrad eventually had to go around front, grab a hammer and bang on the graphite case until he fractured it. Then we were able to pull this out.

Now, in an unmanned situation, if you were doing this by some automated means, you'd be stuck. You just wouldn't be able to do that sort of deployment. But once you have got the gear together there, got some electric source, you could carry it out to where you wanted to go, and I guess if you had a track vehicle you could certainly go out and find a pretty good place to lay it.

Now, as you know, these instruments are pretty sensitive. Take something like the magnetometer. One of the jobs we had to do was move it some 300 feet or 100 feet away from the central station and as far as we possibly could from any other pieces of equipment, because it was trying to measure very accurately very light magnetic fields, and in the magnetic fields the problems that would be induced by metals close by would negate the data we could have received.

If we tried to just mount this on top of something like a rolling vehicle, I think we'd be stuck, because

just by virtue of it probably being made out of metal we would be unable to use this sort of thing. It's possible that we could have set-- Let's say a roving vehicle could have set this piece of gear on the surface. When we set out a magnetometer, that had to be pretty far away from other materials. We set out a seismometer and it didn't have to be so far away from other equipment. As it was, it had to have good, solid contact with the ground. As you recall, we dug a little hole and put down a stool and pushed the stool in so it made good contact with the surface. Then we put our seismometer on it. We aligned it very accurately so we could get some bearings from it and leveled it.

Maybe you could instrument all these sorts of things to do it in an unmanned mode, but my personal opinion is it would be very difficult because the leveling procedures and the object of deploying a magnetometer seem to be completely different than the procedures and techniques and the desires of deploying something like a seismometer.

Solar wind was probably a little simpler. You don't have to move it away from anything, and it doesn't have to be particularly level.

With the suprathreshold ion detector experiment I guess there is the desire there to keep it away from anything that might outgas. If you had a wheeled vehicle, unless you could offload it, I guess you'd have to ask yourself again would there be anything in this total vehicle that can outgas that would give us some bad data in that type of an instrument?

With the cold cathode gauge, the same sort of affair. One of the main problems we had as we laid it on the ground was to be careful not to run over -- in our case step on -- the electrical connections between all these sections. Again, if you had a wheeled vehicle, you'd have the same problem.

One of the benefits of the ALSEP was having it dispersed. All of these instruments were far from each other, and we were able to get independent measurements. Once we had accomplished the setdown on the moon, we were

able to turn it on.

And I think Rocco made one whale of a good point today. We are not in just the manned flight business. We were in the manned business up there on the moon for something like 31 hours that Pete and I were there. We were in the manned business for a little bit less than that on Apollo 11. But once the manned left, either 11 or 12, we have had unmanned equipment up there and operating for a long time. This one has been operating for a year. There is no reason to believe it won't operate for another year right off the bat, and that's a long time.

Sometimes we have a tendency to overestimate the other guy and underestimate ourselves. We have got to-- For example, the lunar surface work that Apollo 11 did. They brought back 50 pounds of rocks. We brought back 75 pounds. And the Russians on their last one brought back two-tenths of a pound.

Now, by gosh, if the Russians were bringing back 50 and 75 pounds and we were bringing back two-tenths of a pound, think how you'd feel. I don't think we'd be so doggone excited as we are about their two-tenths of a pound.

So I would like to say I think that our particular deployment of the ALSET turned out to be I think real well. It is working real good. But the important part I think is we shouldn't underestimate our capabilities and our ability to use both unmanned and manned exploration to its best advantage, and we shouldn't be so concerned I think about just exactly what the other guy is doing until he starts doing the same sorts of things we are doing. He's not coming close yet.

PETRONE: Dick Moke now of the Manned Spaceflight Center will give us a quick overview with a few vu-graphs of ALSEP, what each of the experiments look like, before we go into individual descriptions.

MOKE: May I have the first slide?

(Slide)

NOTE: Not all the slides shown at the News Conference are reproduced in this transcript.

I would just kind of like to briefly reorient you and kind of put the remainder of the discussion in context with what this hardware looks like, a little bit about how it works.

Here's a photograph of the LM. The fuel capsule we talked about is on this side. And here is the hardware as it mounts into the LM and as it is removed.

Next slide, please.

(Slide)

The hardware of the ALSEP that we have been talking about is stowed like this and put in the LM as you saw it. Here is the magnetometer, the solar wind spectrometer, the passive seismometer on this subpackage.

Next slide, please.

(Slide)

And this is the other subpackage. This is the generator, the hand tools, and the suprathreshold ion detector is back on the back.

Next one, please.

(Slide)

This is a photograph of the ALSEP as it was deployed on the lunar surface. You will see that the central station has been erected. The bolts have been taken out. The sun shield where the experiments are mounted has been raised. The antenna has been pointed to the earth. And the experiments have been deployed with their interconnecting electrical cables.

This is the magnetometer that you see in the foreground, the solar wind spectrometer, the suprathreshold ion detector, and the passive seismometer.

Next, please.

(Slide)



The central station electronics, which are in the bottom of the erected central station that you saw, are configured like this. This is a very simple diagram that shows that power is generated by the generator, is provided to the central station and to the experiments. Then data from the experiments comes into the data processor and out the transmitter.

Now, the uplink for the commands comes into the antenna, to the command decoder, and they then are passed on to the experiments and the central station.

Next, please.

(Slide)

Now, this is a simple diagram of how the uplink and downlink work. I think I just described it. We are talking about power, commands, and how the experiments feed in data and get commands in from the central station.

Next, please.

(Slide)

Now, on downlink, this is a sort of a scorecard of how the data is brought down to earth. We are talking about 64 words, and they are assigned to the experiments in this fashion. One word is then multiplexed, and we get 90 channels of engineering data. And this is constant. This goes on all the time.

Next one, please.

(Slide)

And these are the commands. We have a capability of 100. We use something on the order of 67 typically. And they are allocated to the experiments and to the central station in this fashion.

Okay.

PETRONE: Next we are going to have Dr. Latham discuss the passive seismometer and the findings. Over to

your right we have got two recorders that are, in effect, recording the data as we receive it in real time from the moon.

In Dr. Latham's presentation he will start off with an explanation -- I know you can't see the recorders -- but generally of what they do in terms of command. What is a command? How does it operate as far as the passive seismometer is concerned? And why is it necessary?

Gary.

LATHAM: I have said this before, but I think first I'd like to stress that the capability of this integrated system of geophysical experiments is greater than, exceeds in the combined capability of the experiments anything in operation on the surface of the earth now. Sometimes we lose sight of that.

And we are particularly appreciative in the case of the seismometer, in that we can magnify in a sense vibrations of the lunar surface about ten million times. That is, the data that we see recorded on chart paper show vibrations that are ten million times larger than those that actually occurred at the surface of the moon. On earth we couldn't possibly do that because weather and man simply make too much noise here on earth, and seismometers that sensitive would simply be swamped all of the time. But on the moon we can. And this has turned out to be a very favorable factor, of course, for seismic experiments on the moon.

Now, we can control the seismic experiment by means of 15 commands which we send periodically, and these commands do various functions, such as changing the sensitivity of the instrument, calibrating it, and commanding leveling motors which adjust the very delicate adjustments in the instrument.

This morning we thought it would be of interest to you to actually observe the signal as recorded from the moon during one of these commands. And so I am going to step over here and just spend a minute with this recorder.

One set of data shown here will be discussed

later. The other set, for the seismometer, are shown here.

Now, these are recorders very much like those in the Manned Spaceflight Center in Houston that we observe during the mission and actually use later on. The data are displayed continuously in this fashion and correspond here to the four different seismometers that are in the package. So that the displacements, the wiggles you see here, actually correspond to vibrations of the lunar surface.

And when we get a seismic event, these wiggles get very large and are very easy to observe.

Now, what we are going to do this morning for this exercise is send a command which turns on a small motor and drives a gimbal so that we level the experiment very, very precisely, and you will see on this channel the effect of that command being sent, the actual displacement of the seismic boom as it occurs. So keep your eye on that. I realize that you won't see it very well from too far back.

I think we have audio connection with the man in the control room so I just turn it over to them now and let them send this command.

(Demonstration)

The command was sent. Here's the response. You see these, the seismic swinging now.

I think to appreciate that you have to realize that that command was sent to Madrid, Spain, from there to the moon as a coded message, actuated, and the signal back to Madrid and from Madrid to the Manned Spaceflight Center in Houston. I haven't gotten over that myself yet.  
(Laughter)

This is Goldstone. I'm sorry.

Quite a remarkable network. And we heard the number of commands that have been sent. I have forgotten now. Thousands.

PETRONE: 6,500.

LATHAM: 6,500. Later on in the morning I think the magnetometer data will also be exercised so you will get a chance to see that display again.

Now, I have given you a short summary of seismic results to date as recorded by the Apollo 12 station, and I just want to review here in the brief time that we have the essential points as I see them.

We record seismic events now at the rate of about one per day, a little less than one per day. We have also recorded at this station the impacts of the LM and the S-IVB. And these were essential signals for our interpretation of the data because they produce signals so utterly different from those that we normally record here on earth, and we really key all of our interpretation to those signals.

The signals last a very long time, as you know, and they die out very slowly. So without any other fact we could say that the mare structures are clearly quite different from typical earth crustal structures.

We found in the last few months that some of these signals bear a very striking resemblance to one another. In fact, they are identical in every aspect throughout the length of the record. We have been able to identify about nine such sets of matching events, or for a total of 58 in eight months.

It's very improbable that meteorite impacts would produce such signals because they simply would not be expected to strike the moon in exactly the same place repetitively and to produce such identical signals.

The only logical interpretation is that these are moonquakes. And, of course, that excited us a great deal. We had expected that there would be moonquakes, some of us. Some of us even made bets on it. And for the first few months we were not able really to determine that any of the events were. We expected all of them were meteoroid impacts. But now we can safely say I think that in the region of the Apollo 12 station there are at least

nine places at which moonquakes occur, and these occur not at random but every month at or near the time when the moon comes closest to the earth in its monthly orbital cycle; that is to say, at times when the gravitational strain introduced into the moon by attraction between the earth and the moon is maximum.

And so we expect that these must be induced by tidal strain. And the fact that there are nine different sets means that the tidal strain is triggering moonquakes at nine different places at least in this region.

We observed some of these from the Apollo 11 station, and we expect, therefore, that this kind of moonquake is occurring not only in this region but perhaps at many places over the entire moon.

Now, we have tentatively placed the location of the most active zone -- that is, the set of matching signals which have most of the moonquakes -- about 120 miles southeast of ALSEP, very near a set of well developed rilles. Most of you know what rilles are. They are the large cracks or ditches -- we are not sure which -- that we see in the lunar landscape.

But if a seismologist wanted to point his finger at a place on the lunar map and say, "Where do I think moonquakes might be generated?" very likely he'd point out that spot.

So it's a very interesting observation for us. We might interpret this to mean that each month as the bulge of the moon toward the earth increases and strain is introduced into the body of the moon in this way, that the opposite sides of the relationship, the fractures, if they are fractures, actually are forced to slip and that generates the moonquake we see.

Now, the very interesting aspect of this is that-- And, by the way, this would be entirely equivalent to the earthquakes, for example, generated in California by the slippage of the San Andreas Fault. The very interesting aspect of this I think is that the slips appear always to be in the same direction. That is, you don't see a slip in one direction and then a slip in another, but always in

the same direction.

Now, that means to us that there is very likely an additional source of strain accumulating within the moon. And that strain is being triggered -- the release of that strain is being triggered -- by tidal strain.

Now, we can only speculate as to the source of that additional strain. It may be that the ellipsoidal shape of the moon is gradually settling back into a more spheroidal shape as the moon recedes from the earth. We believe the moon to be receding from the earth perhaps half an inch per year roughly. It doesn't sound like very much. But we are not talking about very much energy in these moonquakes.

I wouldn't want to leave you with the impression that the moon is a seething cauldron, cracking all over the place, with lots of energy release. In fact, it's very much less active than the earth. And if we were to extrapolate this rate of activity to the entire surface of the moon, the total energy release would be perhaps a thousand billion times less than the energy released from earthquakes every year.

So it's a very inactive body from that point of view and seems to me to illustrate that we are not dealing with a hot moon. It seems in fact to me very improbable that there can be significant sections of molten moon. There may be isolated pockets. There may be molten moon at very great depth. But it cannot in any sense resemble the earth with moving plates and great mountains being built.

But there is a source of strain, we believe, and what that strain is will be a very exciting problem for future study.

It may be, for example, that the moon is expanding very, very slightly as a result of radiogenic heat release, radioactive materials releasing their heat within the moon. And when we go to the Apollo 14 site we will certainly want to take great care to look at photographs from the Fra Mauro area to see if we can see that displacement has occurred along these great rilles.

We may see one block has dropped down relative to the other side of the rille, and if we see that we will have established in my mind that these are likely great fractures, that these rilles are not simply ditches dug into the lunar terrain by magma flow or hot gases as some speculate. But for the moment all of that is very, very speculative and will certainly need further work to determine.

As I said, all of these moonquakes are small. One concern, for example, was whether or not when such a moonquake occurred and the astronauts were on the surface at the Apollo 14 landing site, which is only 50 miles north of this Fra Mauro region, would they be knocked off their feet or would the LM tumble over and make it kind of rough to get back?

The fact is that an astronaut standing right at the epicenter -- that is, the area at which these moonquakes occur -- would probably not feel the vibration at all. He may feel it through his boots but very likely would not feel it at all.

So the chances for tumbling the astronaut into a big crater or knocking the LM off its pins are very remote I think.

What can be said about the structure of the mare, in closing here, from the unusual signals that we saw? First, the velocities of the seismic waves are much too low to correspond to a solid rock layer. You simply are not dealing with that. In fact, it probably does not-- The velocities do not reach that first solid rock layer until you reach at least 10 or 15 miles into the lunar material.

That isn't to say that it was not once solid. Some investigators speculate that the entire moon was covered with a crust of an orthosite rock, as you may know, which occurred from melting very early in its history, and perhaps that layer of an orthosite rock did exist in this area but was removed by huge impact or pulverized by smaller impacts over the 3.3 billion years or so that these rocks have been in place since they solidified, and that at the present time it can be thought of as a rubble, simply a rubble which consolidates by self-compaction as you go to

greater depth. And, in fact, that is the model that I would favor at this point. And that rubble as it consolidates must persist to depths of the order of 10 to 15 miles at least without a distinguishable major discontinuity or boundary similar to the crust of -- the base of the earth's crust, which we call the Mohorovicic discontinuity.

There is no evidence from the seismic data that such a crust exists in this region. I think we will have to wait until we get direct measurements in the highlands, both seismic measurements, measurements from the other experiments, and samples, to answer this question. Did the moon have a primitive crust which at one time extended in the mare perhaps and has since been removed? Or perhaps these are plates, isolated plates, of crust. These will be of great importance to us in unraveling the history of the formation of the moon and how it relates to the earth.

I might just say we are also recording meteoroid impacts, and we believe we are recording impacts of meteoroids about the size of a large grapefruit or so. Once every month these occur at ranges of up to about, oh, 120 miles from the station. Many smaller ones are recorded, and these eventually will lead us to the first quantitative estimate of the numbers and masses of such pieces of rock material in near lunar space in this size range.

Of course, this will be of great importance to scientists in itself and to engineers who must deal with the problem of building a lunar base for long-term occupation some day, as we fully expect will have to be done.

That's all my remarks.

PETRONE: Thank you, Gary.

We will now have Dr. Snyder discuss the solar wind spectrometer.

SNYDER: May we have the first slide?

(Slide)

I want, first of all, just to show what the solar wind spectrometer looks like. This is a picture



of the way it is mounted on the pallet on the LM. The legs are all tucked up under it. A little sunshade here is folded down to give it a minimum amount of volume. And all of our apertures through which we accept the solar wind in order to make measurements are all covered up with little aluminum, very thin dust covers.

The next slide --

(Slide)

-- shows the way it looks on the surface of the moon except that this isn't the surface of the moon. The legs have been deployed. The sunshield is now up, uncovering these radiators that radiate the internally produced heat to keep the instrument cool in the daytime. And now our dust covers have been thrown off by a command from the ground, and the solar wind is now able to penetrate in where we can measure it.

The next slide, the last picture, --

(Slide)

-- is a closeup of the business end of this. This is the sensor. These little apertures are about an inch and a half in diameter, and there are seven of them, one pointing up and six others pointing around other directions, so that we can accept the solar plasma from whatever direction it may be coming.

The next several experiments that are going to be discussed -- the solar wind experiment, the suprathreshold ion detector experiment, and the magnetometer experiment -- all really relate basically to the same kind of phenomena. They have to do with the charged particle and field environment of the moon.

In our own experiment, the solar wind experiment, we are measuring essentially the basic phenomenon that is involved here. The so-called solar wind is a very hot ionized gas, and physicists use the term "plasma" for this, which exists in space, because the upper part of the atmosphere of the sun is so hot that the gravitational field of the sun is unable to confine it, and so it is

expanding out into space at very high velocities in all directions, filling up the whole solar system with its plasma.

This plasma has various effects on the moon. First of all, it brings a magnetic field to the moon and past the moon, a magnetic field that was originally in the sun itself. And the magnetometer people will be talking about this in some detail in a little while.

This gives them a varying magnetic field that they are able to compare with their instrument and put some magnetic input into the moon which otherwise wouldn't exist.

The solar wind implants gases in the surface of the moon. These gases can be thrown out again, released, by impacts, and we see this going on. It also tends to blow away whatever atmosphere the moon may have had potentially or whatever atmosphere may be produced by coming out of fissures or volcanos or whatever may be outgassing.

And so the solar wind is sort of the fundamental entity in space on which everything that happens -- not everything -- but a wide variety of things that happen in space depend.

The experimental goals of our particular experiment were, first of all, very simple -- to answer the straightforward question with a yes or no answer as to whether the solar wind indeed strikes the surface of the moon. At the time this experiment was first proposed, we had no information on this at all. We got some indirect information that gave us a probable yes answer out of the Explorer 35 which went into orbit around the moon before we got there and is, in fact, still giving data in orbit around the moon.

But with our solar wind spectrometer, we are indeed seeing the solar plasma striking the moon at all the times that we would expect it to do so. I will say a little more about that in detail.

The second scientific objective of our experiment was to attempt to make measurements of the solar wind with

sufficient accuracy so that we could see whether there are any subtle changes in the solar wind properties that are produced near the surface of the moon, perhaps at the dawn and dusk terminators or at any place, and to try to relate these subtle effects, if we find any, to interior properties of the moon or whatever kind of properties of the moon might be causing this.

This second main scientific goal we haven't achieved yet. We are still working on it. It requires a lot more data than we get ourselves. It requires, first of all, that we have detailed information on what the solar wind is away from the surface of the moon in order to be able to make detailed comparisons between that and what we are measuring on the surface of the moon. These measurements must be made simultaneously with ours, must be made in the same general region of space.

And it turns out that inasmuch as the plasma probe that is on Explorer 35, which would be the ideal thing to compare with, being only a few thousand kilometers away, after working beautifully for two years, unfortunately failed about a month before we got there, so that we don't have as much data to compare with as we had hoped.

And so this comparison is taking quite a bit of time. We are still working actively on it, but we don't have any definitive results to announce at the present time. All we can say is that there do not appear to be any major effects on the solar wind by the moon. As near as we can tell now, it simply moves right in and impacts the moon and is absorbed by the surface.

The other thing we are doing with this instrument is to use it as a station to study the solar wind itself. Again it is a question of detailed comparisons between this data and geomagnetic data, data on other plasma probes, cosmic ray data, and a variety of things of this kind.

Now I'd like to go to the next slide which illustrates the environment in which these experiments are taking place.

(Slide)

The solar wind coming out from the sun doesn't actually impact the earth or come anywhere near it. It is, in fact, excluded from a large region here which is called the magnetosphere by the magnetic field of the earth. Ahead of that magnetosphere there is a bow shock that the solar wind passes through, undergoes a transition here (indicating). Its properties are changed. Temperature is increased, and velocity is decreased. Direction of flow is changed.

So inside here you have what you could call the transition region or a magnetosheath where we have solar plasma that has undergone the change in properties here.

This part of the diagram shows one month's motion of the moon. These things are all to scale except for the size of the moon and the earth. Well, I guess I should also say the size of the solar wind spectrometer, which is this little rectangle, is also somewhat exaggerated. But the overall picture is to scale.

You will notice here that from this time up here when the sun sets on ALSEP until around here when the sun rises again, our instrument is in the dark on the back side of the moon where it is shielded from the solar wind by the moon itself, so we have about 14 days out of every month where we don't get any data at all.

Then in this region for about a day we see the undisturbed solar wind just after sunrise.

Over here for about four or five days we again see undisturbed solar wind.

Here about a day and here about four days (indicating).

We spend about four days back in the tail where there is solar plasma they are never able to see, and then about four days in this region (indicating).

And these same three regimes, solar wind, tail, and transition region, are important to the other two experiments that will be discussed after this discussion.

The next slide --

(Slide)

-- just shows a little bit of the kind of data that we get. We have here the velocity that we measure in the plasma. This is a second velocity which is really essentially the thermal velocity that tells us what the temperature is. Down here we have the density of the plasma that we are measuring.

Density is, of course, very small. We notice here it goes from about 1 particle per cubic centimeter up to about maybe 25 is the maximum excursion that we see here.

Here we are in the dark at the bottom end of the picture.

In this region we are in the geomagnetic tail. In this particular month, which was the second lunar day, there are a few hours here when we are in the middle of the tail or would have expected to be in the middle of the tail, and we actually see some data. What we think this is at the present time is that we were so far north of the center of the tail that the wagging of the tail back and forth meant that we actually moved out of it, the whole moon moved out of it, for a short time.

I'm not going to attempt to explain in any detail what all these wiggles are, but you will see there is an enormous amount of detail here. The main thing you can say about the solar wind is it's seldom the same for more than a few minutes at a time. So, whereas the magnetometer may have sort of one event per day to look at, we have something going on most every minute.

The next slide --

(Slide)

-- shows, which is quite different, particularly interesting, an event we have just recently seen that we are now actively studying -- this one right here, this sudden increase in velocity, increase in temperature, and a change in density, all of which occur simultaneously, at

the same minute that there was a beginning of a magnetic storm on earth.

And apparently the change in the solar wind that induced that storm simultaneously moved us very suddenly from in the transition region out into the solar wind.

Here's another event, a rather spectacular one, where there is a sudden change in the velocity of the solar wind.

It is these specific events which we have to find and then have to try to find out geomagnetic field data and various other things to compare it with in order to try to make a total picture of what is going on on the moon.

All this kind of data is interesting to a scientist, and ultimately, once it is all analyzed in detail, of real scientific interest. But it's sort of hard to get excited about because it's a kind of day-to-day thing.

In closing, I want to say a little bit about one particular event that I think is particularly interesting and perhaps not quite so abstruse. That is shown in the next slide.

(Slide)

This is an attempt to summarize the data that we saw on the 15th of April at the time of the impact on the moon of the S-IVB stage from Apollo 13. This impact took place 135 kilometers from ALSEP in the dark and downwind. That is to say, the sun was on one side of us, and the impact was on the other side of us. So that whatever gas was produced by that impact you might have expected to be pushed away from ALSEP by the solar wind.

In fact, what happened is that the impact itself was back here. These are times now -- 1 hour and 10 minutes out to 1 hour and 22 minutes. The actual impact was-- I'm sorry. This is-- Yes, that's right. One hour and 10 minutes. The impact itself was at 1 hour and 9 minutes and 39 seconds, and about 17 seconds after that we saw what may have been the first bare indication of some gas approaching ALSEP from that.

At 52 seconds we have a very clear indication of it -- here a non-zero signal that there is no question about. And thereafter we see various amounts of current as a function of time as shown here.

It is interesting that the suprathreshold ion detector also sees this event. In fact, they saw it before we did because they happened -- well, because they have real-time data of this kind on the recorders. We don't have that real-time kind of data. And at this particular time they saw the maximum amount of current. And we see also coming down from above an amount of current that corresponds very closely to what the suprathreshold ion detector sees. This occurred at 75 seconds after the impact.

Our fluxes agree quite well, and, indeed, we both see that this corresponds to particles having energies of about 35 to 50 electron volts.

The suprathreshold ion detector has a very narrow field of view pointing approximately upward, and this data point here corresponds to our upward-looking cup. All the rest of the data on here corresponds to one or more of the cups that are looking in the horizontal direction, and, as a matter of fact, this is by far the biggest signal we ever see in the upward-looking cup. In general, the other signals we see are just barely above our sensitivity, which is quite a little bit less than the sensitivity of the suprathreshold ion detector.

Both of us are studying this event actively at the present time, and all we can say at the moment I guess is that it's very intriguing and quite puzzling.

And let me just show you in closing a few of the phenomena here that have us puzzled. Dr. Freeman will try to put this into a theoretical context in a little while.

We think that there are three distinct clouds arriving here. I have called them A and B and C. They have somewhat different energy properties, somewhat different mass properties. The suprathreshold ion detector gets some mass information. We don't get any. And, in particular, different directional properties.

Now, it may be that these three are really

separate events, or maybe they are all one. I don't know. But the next slide illustrates the directional properties.

(Slide)

Here we see our solar wind spectrometer looking down from above. The sun as I say is off to the east. The impact was off to the west. And this first cloud which arrived about, oh, one or two minutes after the impact started approaching from this direction and swung around gradually and at the end of that it was approaching from this direction (indicating).

The great bulk of that which is indicated by the larger circles here was coming down from the north, although the impact was in the west.

The second little peak here was coming from this direction, sort of northeast, and the third big peak started out coming from this direction down from the north and a little bit east and swung gradually around here.

So what we have here is some kind of a very complicated gas flow which is sort of swirling, moving primarily in the horizontal direction, so that the vertical-looking cup sees almost nothing or just a very few picoamperes of current, and coming in from the various directions at the side we see something like a hundred times this amount of current.

We will be looking forward to another impact like this from the S-IVB on Apollo 14. We are also very much hoping along with the magnetometer people that we will have some meteor impacts that are big enough to throw out an amount of gas such that we will be able to see it.

And I think this is a particularly interesting example of the way that the various ALSEP experiments work together. The seismometer sees the shaking of the surface by the impact. We see the gas that the impact releases. And it may be that on some future events, if the magnetometer is operating at the proper time, we will see changes in the magnetic field from events of this kind.

And so all of us that have been involved in this



are really quite pleased and impressed with the effective way in which all of these experiments are being able to shed light on the various strange things that go on on the surface of the moon.

PETRONE: Thank you, Dr. Snyder.

Let's have Dr. Freeman give a discussion of the suprathermal ion detector.

FREEMAN: I see that the data from the SIDE, as we call the suprathermal ion detector, is being put on the Sanborn recorder up here on the left and speeded up a little bit so you will be able to get a better idea of what it looks like. That's a little faster than it needs to be going, but that's okay.

We are on these three channels here. This channel represents housekeeping data and tells us where we are in our stepping sequence with the instrument. This channel over here shows the actual data from one of our two sensors. And at the moment I see it is indicating some fairly substantial activity.

We are now outside the bow shock region and in a region where we see some ion clouds that I will speak a little bit more about in a minute.

But while I am in the process of mentioning the data, I would like to take a second or two to say that I have personally been extremely impressed with the quality of the data from the ALSEP station, and I think some congratulations are in order to the Manned Spaceflight Center, ALSEP Control Staff, as well as the Bendix Corporation that was responsible for the fabrication of the ALSEP central station.

I have been working with spacecraft data for something over ten years now and something in the vicinity of half a dozen satellites or so, and this is by far the cleanest data that I have had to work with to date. By that I mean the noise in the signal is at the lowest level I have ever encountered. This is particularly helpful to those of us who like to process satellite data, large quantities of satellite data, directly with computers, because one of the

biggest problems is to teach computers how to recognize noise when the satellite signal is not clean.

Again I want to thank MSC and the Bendix Company for the marvelous job they have done on this particular spacecraft.

Now, to go on and talk about the instrument and the data itself, the function of the SIDE experiment, very succinctly, is to measure the ion environment of the moon to try and determine whether or not the moon has an equivalent of the ionosphere we find at the top of the earth's atmosphere.

I'm pleased to say that we have found the moon does have a detectible ionosphere. It is quite a different kind of ionosphere from what we have found on the earth. This is perhaps to be expected since the environment in which the moon resides is extremely different from the earth's upper atmosphere.

The first slide --

(Slide)

-- is an indication of how the instrument looks as it is sitting on the surface of the moon. This is a photograph that was taken by our good friend Al Bean shortly after he completed the deployment of the suprathreshold ion detector experiment.

The ions enter the instrument through two apertures at the top of the device. As you can see, these two apertures represent a look angle into space which is, as Conway mentioned, approximately in the vertical direction. Because of the fact the instrument is very sensitive and capable of making a mass analysis on the ions as well as an energy analysis, the field of view of this detector is extremely small, measuring about 6 degrees on a side, for a square solid angle.

The instrument sits on legs, as you can see, three tripod legs, and the top of it is about 20 inches above the lunar surface.

There is also deployed by the astronaut, not too visible in this picture, what we call our ground plane grid which looks sort of like an umbrella without any cloth on it, and its function is to allow the instrument potential to be referenced with respect to the potential of the lunar surface. I won't go into that in any more detail.

Let me try to discuss the data by saying that in a gross sense we are able to categorize the data that we have found in two general groups. The first group would be that class of data which corresponds to events which are experienced repetitively on successive lunar orbits -- that is, a phenomenon which is found in the same place every time the moon goes through that phase. This is what we refer to as diurnal phenomena.

The second type of phenomena would be what we could classify as singular or randomly occurring events. An example of that would be such things as magnetic storm activity or the S-IVB impact that Dr. Snyder mentioned.

If I can have the next slide, then, I will outline for you what kind of things we have found in the way of diurnal phenomena.

(Slide) Figure 1

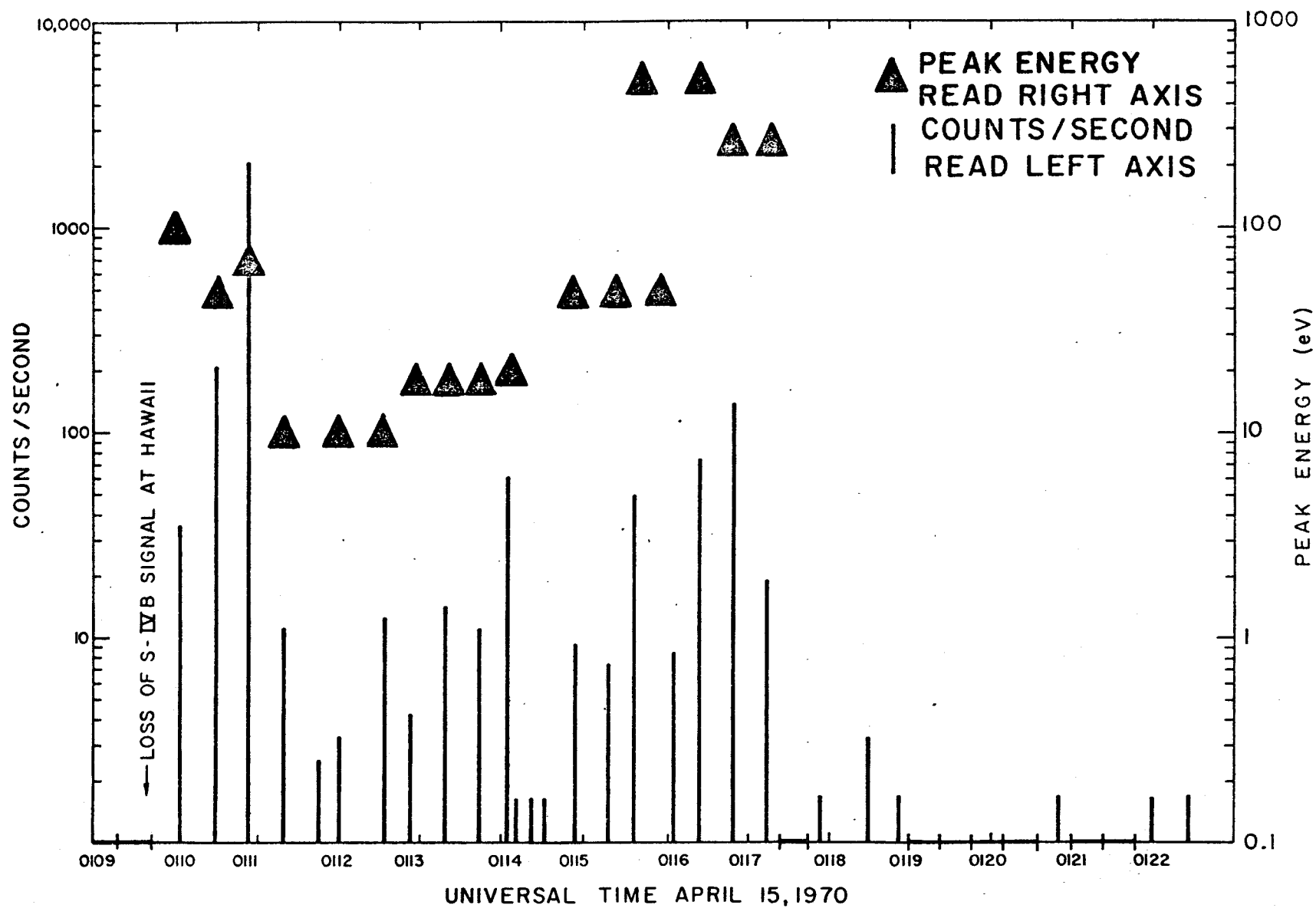
This is again a slide that shows the orbit of the moon, as it moves around the earth, and with the sun up at the top. We see now our familiar magnetopause, the boundary of the earth's magnetosphere, the bow shock front standing out in front. These small arrows represent the direction that our instrument is capable of looking as a function of time as it goes around the lunar orbit, so it gives an idea of where we are looking in space.

Also marked on here are what we call ALSEP sunrise and ALSEP sunset and ALSEP midnight and noon.

These points here, then, represent the terminator crossings which are the crossings of quite substantial interest to us.

The first and perhaps most interesting feature of the diurnal phenomenon is indicated by these brackets here and here which are regions of the lunar orbit in which we

26A



observe what we have chosen to call ion clouds. Now, these ion clouds are bursts of ions which are of low and intermediate energy and moderate intensity. We call them clouds because they have a tendency to come and go, sometimes remaining over a period of 10, 15 minutes, and then they will disappear and we won't see them again for periods of an hour or so.

There is, of course, in dealing with a single instrument such as this the intrinsic problem that we don't know with a single-point measurement in space whether what is actually happening is that there are clouds that are coming and going or whether the phenomenon is being moved in and out of our field of view of our detector and actually is there continuously if we had eyes looking in the right direction to see it.

This basic space-time ambiguity I guess you might refer to it as is something that we hope to be able to shed some light on with some of our future missions, and on Apollo 14 to be launched in January we hope to still have Apollo 12 operating, and thereby get data from two successive points and thus be able to determine whether or not this phenomenon is indeed a sporadic ionosphere or whether one which is something which is there continuously and we are only seeing it periodically.

I might mention that one of the unique and interesting features of this ionosphere, if one actually chooses to call it an ionosphere, is the energy range of the ions. It seems clear that whatever ion constituent is present in the lunar atmosphere is apparently being accelerated by some mechanism, and, of course, that mechanism is a matter of considerable interest and conjecture, and I'll have a little bit more to say about that with regard to the S-IVB impact in a moment.

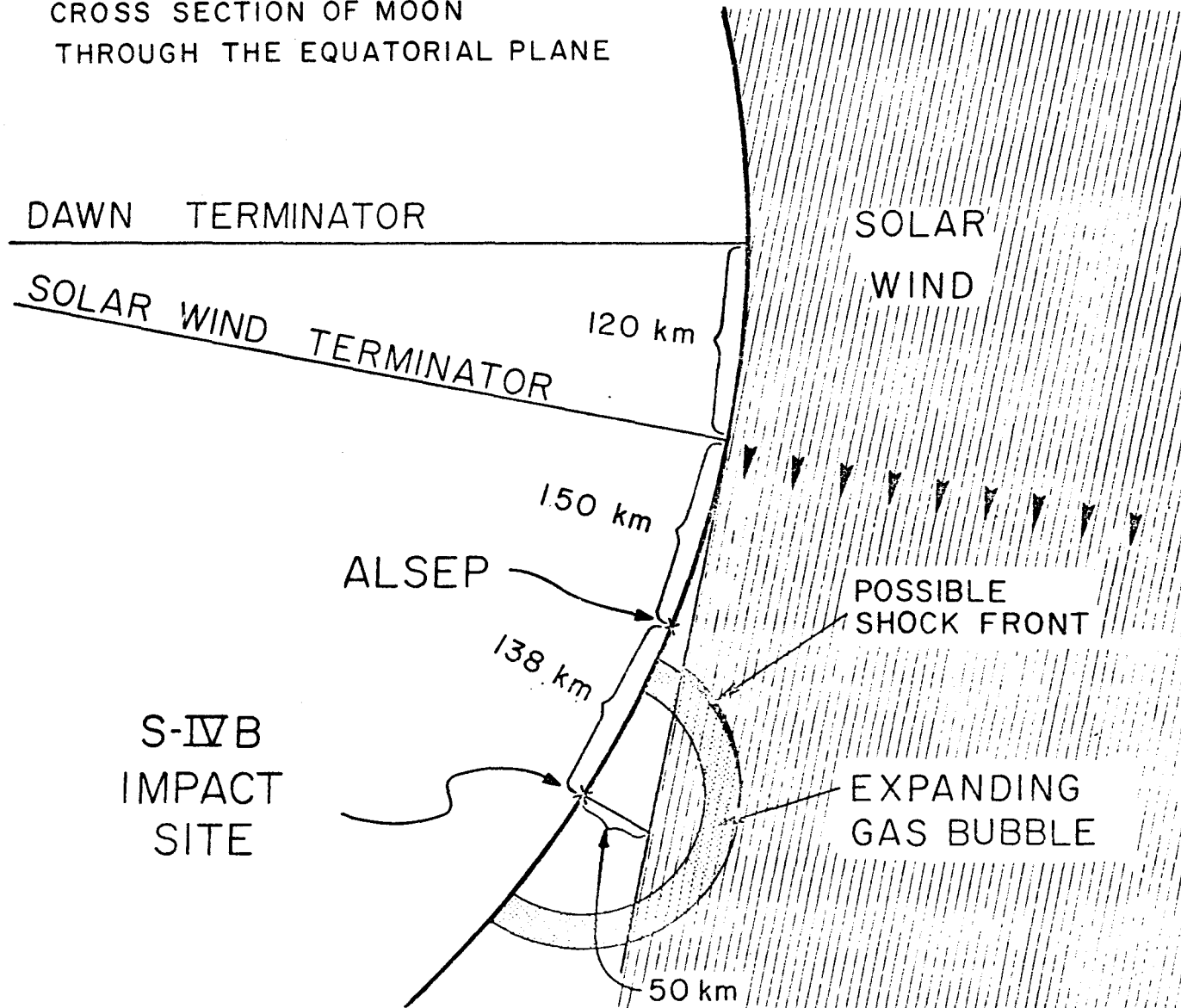
Moving on to the next slide then takes us to the S-IVB event.

(Slide) Figure 2

The S-IVB event, as Dr. Snyder mentioned, occurred on April 15th of this year. The loss of signal at Hawaii was around 0109, 39 seconds universal time. And this graph represents the profile of ion fluxes that were seen as a

↑  
TO SUN

CROSS SECTION OF MOON  
THROUGH THE EQUATORIAL PLANE



function of time following that event by the SIDE detector.

Generally speaking, if you hold this profile up and match it with the fluxes seen by Dr. Snyder's experiment, there is a fairly good match. However, we are in addition able to add some mass information to this picture, and this mass information tells us that it seems quite likely that the ion fluxes being seen at this time were generated by a gas cloud associated with the impact itself and not a modification of the direction of the solar wind. This is extremely important in the interpretation.

Also shown in this graph are the red triangles which indicate the energy spectrum of the ions that were seen following this event, and you read the energy spectrum by looking at the righthand ordinate on the graph. And you notice that during this early initial burst we have energies of the order of approximately 50 to 100 ev as not atypical. The energy then falls to something like 10 ev with a subsequent increase up to energies of the order of about 500 electron volts.

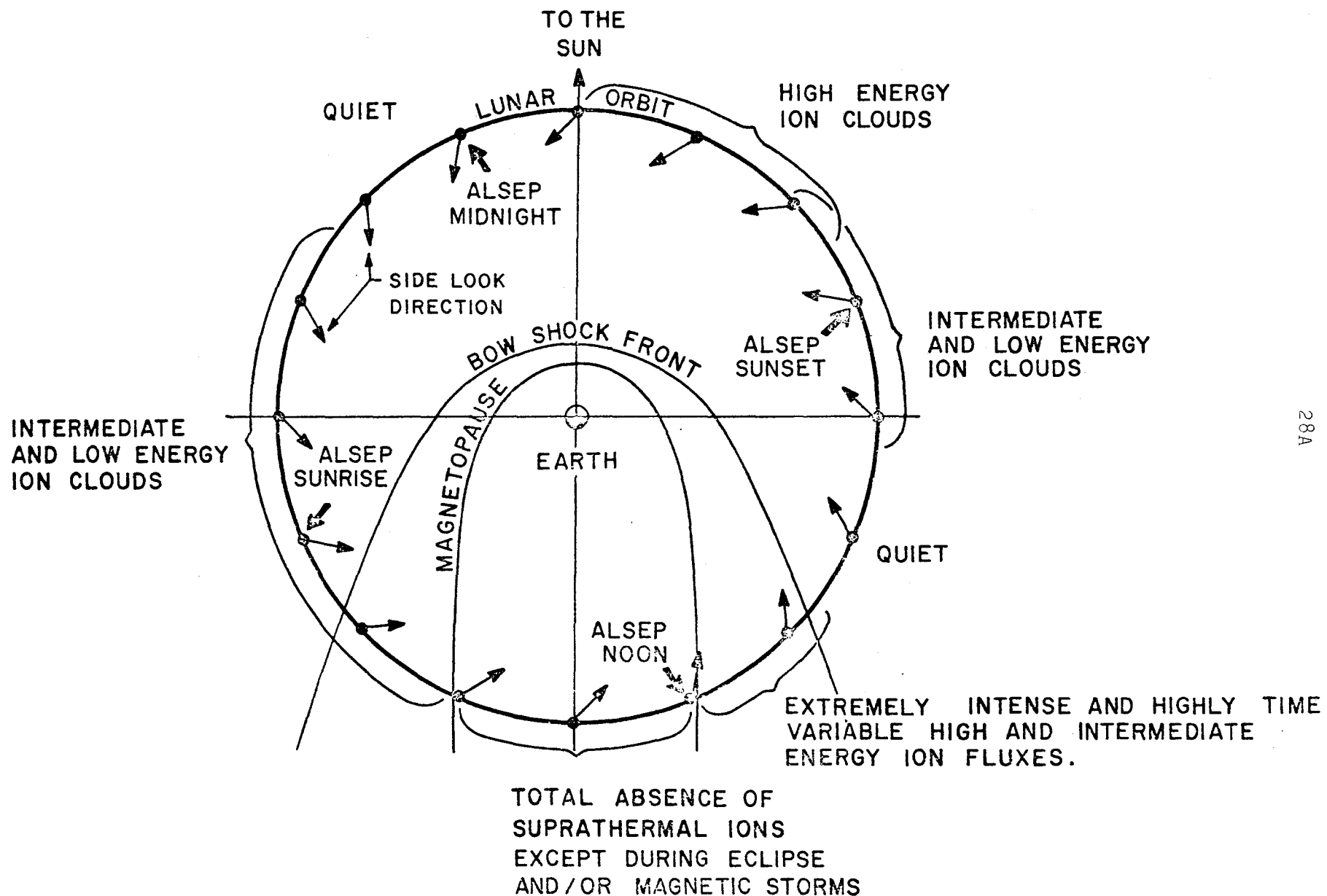
So, again, the question that we must ask ourselves is: How does what must certainly initially be a neutral gas cloud associated with the impact propagate outward, result in ions, and these ions subsequently being accelerated to these quite unusually high energies?

There are two conceivable theories I think that one might consider at the moment as possible explanations. The next slide will give us a handle on this.

(Slide) Figure 3

This is a slide which shows a graphic description of where the impact site is with respect to the ALSEP site. This is an equatorial cross-section cut through the equator of the moon. Also illustrated is the solar wind terminator which, by the way, does not necessarily coincide with the dawn terminator. The solar wind may reach the surface several hours before sunrise under certain conditions.

The picture that is illustrated here for the possible explanation of how the ions generated downwind





could arrive at the ALSEP site is that we envision a gas bubble, a neutral gas bubble, expanding outward from the impact site. This gas bubble, after traveling approximately 50 kilometers vertically upward from the lunar surface, will encounter the solar wind, and also after traveling a little bit farther will encounter the ultraviolet from the sun, and both the solar wind and the ultraviolet from the sun are capable of ionizing this neutral cloud to produce at least a fractional ionization thereof.

If the cloud continues on outward, it's possible for the ions to be picked up and accelerated, and this is the first of two possible theories -- picked up and accelerated by the interplanetary electric field which is the direct result of the high streaming velocity of the solar wind itself.

Now, as the gas cloud moves out to the position where it is above the ALSEP site -- remember we are looking relatively vertically -- then the interplanetary electric field would have to be in such a position to drive the ions essentially vertically into the surface of the earth.

This configuration for the interplanetary electric field is not impossible, although it is not the most common configuration.

That fact led us to a second hypothesis for the explanation of these ions associated with the impact event, and that's the concept pictured here. If one calculates the neutral gas density associated with the ion flux, it's possible to determine the interaction cross-section between the neutral gas and the solar wind and thereby determine whether or not there is enough pressure in this gas bubble to actually stand off or deflect the solar wind.

Now, it appears that this might conceivably be possible, in which case we have hypothesized tentatively the existence of a shock front associated with the gas bubble. In this case the ions as seen by both the SIDE and the solar wind spectrometer would be a shock-front, temporary impact-induced shock-front origin.

As I mentioned, there are two theories, and we must try to establish which of these two is more nearly correct. It's possible that these two theories are also

applicable to the ion gas clouds that I mentioned are seen within several days of the sunrise and sunset terminator and are of natural origin.

One then I guess could say that here we have a situation in which we have an artificially-induced gas cloud associated with the impact event of fairly well known gas content which is liberated in known time and can be studied by the instruments, which when properly understood must almost certainly shed some substantial light on a very similar type of phenomenon which is being seen naturally in the vicinity of the sunrise and sunset terminators.

So this is I think an example of how this impact experiment can ultimately move to help us understand this sunrise-sunset ionosphere.

There were some other items in the diurnal phenomenon that I didn't take time to mention. They include fairly energetic ions that are seen from the earth's bow shock front upstream. They include substantial activity in the earth's tail.

I think I am pretty close to exhausting my time, so let me proceed then to the next slide which is a summary of some of our principal findings.

(Slide) Figure 4

Item 1 is what I have just discussed, the ions associated with the S-IVB impact.

Item 2 is the similar energy ions found surrounding the lunar sunrise and sunset.

Item 3 is a reminder that we think that possibly the same mechanism is working for both of these two phenomena. However, this mechanism remains uncertain. We certainly hope with more than one instrument operating simultaneously we will be able to shed some light on this.

Item 4 is this discussion of some very energetic ions that are found during the lunar night, evening and night, and again some ionospheric interactions associated with the passage of the moon through the earth's bow shock

## PRINCIPAL SIDE FINDINGS

1. THE S-IV B IMPACT PRODUCED AN INTENSE BURST OF SUPRATHERMAL IONS.
2. SIMILAR ENERGY IONS ARE REGULARLY FOUND SURROUNDING LUNAR SUNRISE AND SUNSET.
3. THE ACCELERATION MECHANISM OR MECHANISMS FOR THESE IONS IS STILL UNCERTAIN.
4. ENERGETIC IONS THOUGHT TO BE FROM THE EARTH'S BOW SHOCK ARE FOUND DURING THE LUNAR EVENING AND NIGHT.
5. INTENSE ENERGETIC ION FLUXES ARE FOUND DURING THE MAGNETOPAUSE, MAGNETOSHEATH AND BOW SHOCK CROSSINGS.
6. NO ION FLUXES ARE FOUND IN THE MAGNETOTAIL EXCEPT DURING A MAGNETIC STORM/ECLIPSE INTERVAL.  
THIS IS A VERY SURPRISING RESULT !

and magnetosheath, which is another story in itself, and I won't take the time to go into it.

Item 6 is an item that I was even a little bit reticent to include in the list. However, it is quite exciting, although very preliminary. We have found a surprising absence of ions in the magneto tail. This would be during the intense portion of the lunar day -- that is, around noon.

Now, there are some problems associated with the direct interpretation of this data, and one problem may be the local magnetic field that has been found by the magnetometer experiment. It is conceivable that this local magnetic field has an effect of modifying the ion trajectories as they are trying to approach the ALSEP site and hence essentially shielding us from the full phenomenon that may be coming from the areas more distant surrounding the moon.

Again, this brings me to the conclusion that if we can get another SIDE and ALSEP set up operating in another lunar location where the magnetic field may be different and perhaps even considerably lower than this, we may be able to shed some light on this Item No. 6 which has a severe question mark after it at the moment.

Ideally, in order to fully understand the lunar ionosphere, it would be desirable to have a complete network of ALSEP stations strung at different places around the moon. We know in order to completely examine the earth's ionosphere it requires a large number of stations at a variety of different latitudes. It doesn't appear at the moment that such a complete network of stations for the moon is in the offing.

And the last slide is a small cartoon I clipped which expresses the situation very succinctly I think.

(Slide)

(Laughter)

Thank you.

PETRONE: Thank you, Dr. Freeman.

We will now have Dr. Swann give us a resume on the

field geology investigation.

SWANN: The geology experiment is not really an integral part of the ALSEP, but I guess since we loaned them our rock hammer to help remove the fuel cast from the container, that this qualifies us to talk at an ALSEP anniversary. (Laughter)

But, seriously, I think there are several disciplines of experiments that have been flown in our past two missions. The disciplines of geophysics, geochemistry, and geology are already at this early date and only after two missions beginning to get information that from one discipline is starting to support information and ideas that are obtained from the other disciplines.

Let's go to the first slide.

(Slide)

I think this is our first look at the moon today. Apollo 11 brought back about 50 pounds of rocks from Mare Tranquillitatis. Apollo 12 returned about 75 pounds of rocks from Oceanus Procellarum. One of the more interesting things about Apollo 12 is that it landed on one of these visible rays of ejected material from the large crater Copernicus, and we feel fairly certain that we have samples not only representing the darker mare material of Oceanus Procellarum but also some of the material that was originally derived from the Copernican event in this area.

The next slide, please.

(Slide)

This is an Orbiter photograph of the landing site, the crater in which Surveyor 3 landed right in this area. The location of the Apollo 12 LM was right about here (indicating).

Now, a number of geologists have contended for many years that a lot of features, the craters that have been seen through the telescope on the moon, are impact-origin craters that are formed by meteorite impact and

possibly some cometary impact. This has been very recently supported I think by the seismic findings of actually measuring what appear to be impact events on the lunar surface.

Well, it follows then that if you have impacts occurring at regular intervals on the lunar surface, then the lunar rocks will probably be pulverized to form a lunar soil or what we commonly term the lunar regolith. This was predicted prior to the first lunar landings.

The unmanned Ranger series helped support this notion. The Surveyor series showed the moon was indeed covered with fine-grained what appeared to be fragmental debris. And the Orbiter series showed this kind of material, this covering, is essentially lunarwide in nature.

The Apollo 11 missions then have returned some of that material. Again, it looks like it has been derived from pulverizing the preexisting rocks. Shock effects are noticed in the rocks that are impact derived, and thus we can see that many of the surface features such as these craters which are abundant and universal on the moon are probably impact-derived, which then tells us again what is most of the important mechanism or the major mechanism in modifying and forming the features we see on the lunar surface.

Next slide, please.

(Slide)

This is a map of the traverse that Pete and Al took. These various numbers-- Actually, the LM landed about here. These various numbers show the distribution of the returned samples. Now, many of the samples we have been able to locate with a fair degree of accuracy and certainty simply from their transcript. Many more we have been able to locate very precisely from the returned photographs and obtained an orientation, the orientation in which they were sitting when they were on the lunar surface.

We will go in a minute to this little crater which we call Block Crater up on the inner flank of the Surveyor crater. This was one we were particularly interested

in getting samples from because we believe that it excavated through where the regolith is very thin into the local bedrock and actually had ejecta around it that is representative of material that was originally formed right in this area.

And the reason we were able to predict that this would be a very blocky crater and that the blocks looked like they were locally derived was from the photographs returned by the Surveyor spacecraft.

We worked with Pete Conrad and Al Bean up to a week before flight time working out various potential traverses where the landing site would be, and this was one crater that they were well aware of was of a special interest to us to get samples from, and they did return some samples from that crater.

Let's go to the next slide.

(Slide)

This is a view taken during the Apollo mission of the Surveyor spacecraft, and this very blocky crater and its associated ejecta field.

Next slide.

(Slide)

And a closeup view of what the rim material looked like. We were after fragments that were scattered around in here. Actually, the fragments were collected from somewhere down in here (indicating).

Next slide.

(Slide)

These two we think probably are representative of the bedrock in this immediate vicinity and not necessarily some (erratic) that was thrown in from the crater Copernicus or any other of thousands of impact events from many miles away.

One is this rock No. 46 sitting on the surface --

a picture of it in the lunar receiving laboratory -- and rock No. 47 and its accompanying picture.

The next slide.

(Slide)

This is actually an Apollo 11 shot. We noticed on all of the Surveyor missions, the returned television images, and on the Apollo 11 photographs that the surface is typically darker where it has been disturbed. It looks like the material just under the surface a millimeter to two deep is somewhat darker, about 30 percent darker, than the normal surface, undisturbed surface.

The next slide.

(Slide)

On the second EVA, first stop after the revisit to the ALSEP, Pete and Al noticed very early that they were kicking up -- this is over in the area of Head Crater -- kicking up what appeared to be significantly lighter-colored material. They were able to recognize this on the spot and selectively collected some of that material. Analysis of it shows it to be anomalously -- anomalously for the moon -- potassium-rich. It's very glassy in nature. And we think it is very likely material that was derived from the crater Copernicus event and represents probably a spotty and probably not very uniformly distributed deposit of material from the crater Copernicus which has been somewhat covered and somewhat mixed by local cratering events, but still enough of the material present at the surface to produce the light-colored rays we can see in the telescope.

So we think we likely have a sample that is returned from actually 370 kilometers from its original source, and we have that sample because the crew was in a position to see that they were dealing with something that was different from the typical surface material and brought back a sizable sample of it.

The next slide, please.

(Slide)



On the Apollo 11 photographs we noticed some little linear grooves or striations in the surface that were not reported by the crew. We had a few stereo pairs of these, and we studied them in some detail. And in the Apollo 11 site these things have a pronounced trend in the northeast and northwest directions.

We asked Al and Pete before the mission -- showed them some pictures of these things, asked them to watch for it and see if they saw them, talk about them and photograph them if they were encountered. This is one of the first things they saw, the presence of these linear grooves. They are very faint. They are difficult to see without stereo. But this is a picture taken prior to the first EVA from the LM window and you can see I think if you really look closely a grain or little lines running in this direction and a few running in this direction essentially parallel to the sides of this rather square crater.

There are three trends of these in the Apollo 12 site, northeast, northwest and to the north, and two sub-trends or two somewhat weaker trends. Comparing those trends obtained from linear structure, probably structurally derived or things reflected in the lunar bedrock, we get good agreement from the Orbiter photos we have worked on and we get good agreement from the Ranger photographs.

Going on up in scale, these trends agree from the Apollo 12 almost precisely with those obtained as early as 1964 through telescopic observation of major lunar structural features such as the sides of large polygonal craters, the straight rilles, and some of the segments of the so-called sinuous rilles are somewhat rectilinear in pattern.

We interpret this to mean then because of the geometrical similarities that we are seeing structure in the lunar bedrock reflected at scales of a few centimeters on up to scales of features the size of tens and even hundreds of kilometers long.

Now, if you go to cratering rate curves -- and this is somewhat of a gross estimate but it gives a handle -- we can make an estimate of how long it would take to turn over the regolith to the depth of one of these little grooves, and it's on the order of a few million years. So these things are relatively young features if you are

thinking in terms of the 3 and 4 billion-year age dates we're getting. These things could not survive on the surface for longer than a few million years. If they are structurally derived-- Well, this tells you then there must be some mechanism that is forming them recently, relatively recently, or else that they are being rejuvenated.

We interpret these to be surface reflections of movement along joint planes in the underlying bedrock. The fine-grained material above moves in a sympathetic sort of way and forms little linear features that are reflecting the structural grid or the tectonic patterns of the front face of the moon. We think that they are probably -- that the movements are seismic in origin and some of them are probably impact-derived.

We see a concentration of linear features that are a few tens of meters long around the intermediate-scale craters. This could be because, one, the crater helped make more joints. I think it's more likely that the joints are already there and the impact event jarred the bedrock and we go on.

The other possible origin for these is produced from internal seismic events of the kind Dr. Latham mentioned a while ago and may very well be related to tidal deformation.

I think, in quick summary, that probably the single most important thing in having a man on the lunar surface is the business of being able to make an on-the-spot judgment as was made to collect the light-colored material, see it as anomalous material, be selective about what he says and what he brings back, and being able to make that kind of on-the-spot decision.

On the little linear grooves, for example, we had 90,000-some Surveyor photographs of excellent high resolution, TV quality, that came back. They were not noticed on those photographs probably because of the interference of the scan lines. With the manned missions we have been able to bring back very excellent high-resolution photographs. In fact, Pete and Al took I think 619 Hasselblad photos while they were on the surface, plus all those they took out of the spacecraft window, and from these fine film images we have had a tremendous amount of information, and I think we have just

scratched the surface on these 600-and-some photos. We have a lot to work on yet.

PETRONE: Thank you, Gordon.

We will next have the presentation on our last experiment on the ALSEP. It will be the lunar surface magnetometer. We're going to start with Palmer Dyal going through one of the calibrations on the lunar surface.

DYAL: The results of our experiments are a direct measurement of the magnetic field on the lunar surface, and from these measurements we have been able to calculate an internal temperature of the moon. The first vu-graph shows the magnetometer as it is setting on the lunar surface presently.

(Slide)

Seen here on the foreground on this side of the small crater.

The magnetic field is detected by three sensors located at the ends of these three booms, and the intensity is about a thousandth that of the earth. And the instrument measures the intensity as well as the direction and in the gradient mode measures the difference in intensity of the field across the dimensions of the instrument.

The experiment also consists of a magnetometer located in an orbiting spacecraft, Explorer 35, which orbits the moon at an altitude of about half a lunar radius to about 5 lunar radii.

This instrument measures the input solar magnetic field that arrives at the moon with the solar wind, and this particular instrument measures the lunar response or the output of the moon due to the transformer action that generates eddy currents deep in the interior of the moon.

The next vu-graph --

(Slide)

-- is a blowup of a strip chart recorder that I will show you where I have taken a photo of some data taken

late last December. Up here are the outputs of those three magnetometer sensors located at the ends of the booms shown in the picture. This is one sensor, the second, and the third (indicating) and here are the outputs of the orbiting Explorer magnetometer.

I picked an event where there is an abrupt change in the solar magnetic field that is coming with the solar wind, and you can see this abrupt change here on the orbiting spacecraft, and then as the eddy currents are driven in the interior of the moon, the resistance of the material slows down this abrupt change to something like this as we measure on the lunar surface.

Could I have the lights, and we can look at a calibration of the device.

These three traces show the outputs of the three sensors.

(Demonstration)

The command has just been sent, and this will turn three motors on which reorient the sensors, will also turn a sequence on which internally calibrates each of the sensors simultaneously. You see the X sensor driving up here, the Y, the Z. And this goes through a set of stored calibration amplitude rasters, and then in the middle of those sequences the motors are turned on which reorient each of the flux data sensors.

I guess that explains the operation of the instrument.

Dr. Sonett will continue the discussion by giving some of the results.

PETRONE: Dr. Sonett now will discuss the implications and the findings that have come back in the past year from the lunar surface magnetometer.

SONETT: The magnetometer experiment provides baseline data as mentioned to you by Dr. Snyder in particular and by Dr. Freeman for determining the magnetic field in the solar wind and that forms a complete nest of experimental material which can be used to probe the neighborhood of the

earth and to study the solar wind in itself.

The other type of problem for which the magnetometer is particularly suited is to investigate the internal problems of the moon, particularly the thermal structure and the geochemical structure, and that's what I will address the majority of my comments to.

The experiment so far in the first year has returned something of the order of 2 million bits of data, and it is still operating. The particular things that we look for are fossil magnetism on the surface of the moon and, secondly, as Dr. Dyal mentioned to you, the effects of influx of electrical induction in the interior of the moon.

Let me turn for a moment to the way this is done. Could I have the first slide, please.

(Slide) Figure 5

It's very important to consider the neighborhood problem, that is, exactly where the magnetometer and the moon are. In this region, as you have seen from similar slides, the moon is exposed to the direct influence of the solar wind, and this provides us with a particular category of data family, the data used for exciting currents in the lunar interior.

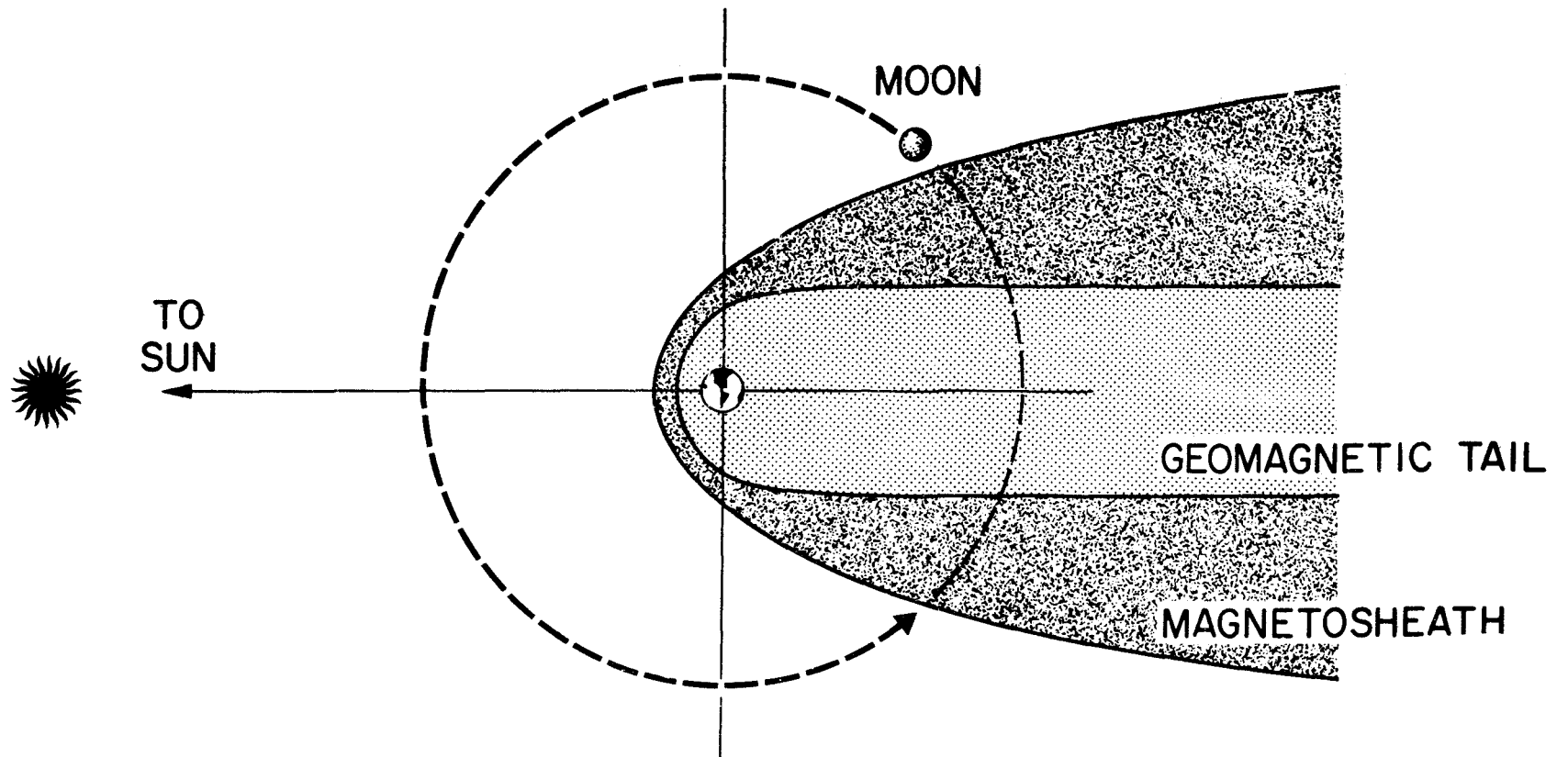
The same thing happens when the moon is in the magnetosheath and the shock solar wind. There the data is somewhat more variable but in its own way more interesting.

When the moon is in the magneto tail of the earth, things are relatively quiet. There is no solar wind blowing, so that is where one looks for steady magnetic field. At least that is where one looks for steady magnetic field using a surface magnetometer.

The experiment consists, as Dr. Dyal pointed out, of a combination of the lunar surface magnetometer and one in orbit on Explorer 35 which was launched about two years before the LSM was landed. The object of this, of using the 35 and the surface magnetometer, is a little bit like the problem of impacting the S-IVB stage for the seismometer. We are far more fortunate. We don't have to go to the vast

# LUNAR ENVIRONMENT

INTERPLANETARY SOLAR WIND



Wagnerian efforts in order to get signals into the moon.

May I have the next slide, please.

(Slide) Figure 6

This is a very quick compendium of what we know about steady field in the moon as measured by this particular pair of magnetometers. There is, of course, additional information from study of paleo magnetism from the returned samples which is actually quite exciting, and also there are measurements made from Explorer 35 alone.

But the LSM on the surface did detect a field of about 35 gammas. That's a field about one-one-thousandth of the earth's surface field. We know that it is localized, that it's not more than 200 kilometers away if you assumed it were a point, that is, a very intense magnet. It was not more than 200 kilometers away from the LSM and not closer than about 200 meters. This is arrived at by using Explorer 35 which shows that the field is not global with respect to the moon and the combination of measurements from the LSM, the intensity measurement and, as Dr. Dyal mentioned, what is called the gradiometer measurement -- that is, how rapidly the field changes from one end of the magnetometer to the other, which is a distance of about 2 meters.

It's very likely that we are looking at a fossil field. This is a field that was inserted 3-1/2 billion years ago or longer. And the reason for that is that the field was locally associated with the magmatic material in the mare. And that magmatic material, of course, has a last thermal episode somewhere in the 3.2 to 3.7 billion years depending upon the particular samples.

And it is known that to put this kind of field into rock there must be a field of a background considerably larger than what you see, and, secondly, the material must have cooled through its curie point so that the field is frozen into the rock.

So from the standpoint of importance or what this sort of thing means, it means that likely lavas were required, melting, and, you know that of course from the geochemical evidence. The existence of a background field.

## DISCOVERY OF STEADY FIELD

- 1/1000 OF EARTH SURFACE FIELD
- LOCALIZED – LESS THAN 200km AWAY
- LIKELY FOSSIL (PALEO) MAGNETISM
- IMPORTANCE
  - REQUIRED LAVAS (MELTING)
  - BACKGROUND FIELD
  - 3.5 – 4.7 BILLION YEARS AGO
  - CLOSE APPROACH TO EARTH OR HOT, SPINNING MOON (DYNAMO)



And the ages. I said 3.2 to 3.7 billion, but we're not really certain that the source isn't really older than that associated with the original formation.

And lastly there is, of course, the very interesting question besides the thermal episode that is required: Where did the background field come from? For reasons I don't have time to go into, it doesn't seem like it was a solar wind magnetic field. And the only other kinds of fields that are convenient in a simple model would either be that the moon were spinning like the earth is, had a hot interior at that time, therefore made a dynamo like the earth's dynamo, and as the magmatic episodes took place, these fields were frozen in.

The other possibility is, of course, the moon was closer to the earth and sufficiently close so that it was inserted in the earth's magnetosphere.

Now, that again is a rather dramatic kind of episode, and I don't have time to go into the consequences of it. It's a disturbing model to many geophysicists because it means rather violent effects were taking place on the surface of the earth at the time of that close approach.

In its favor I will say that we know the moon is receding from the earth today.

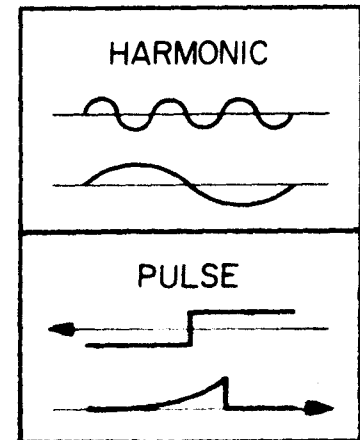
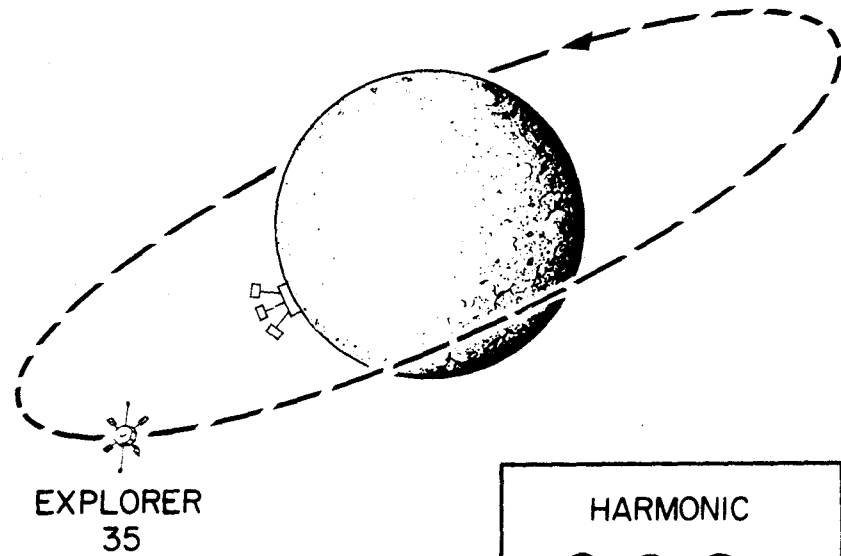
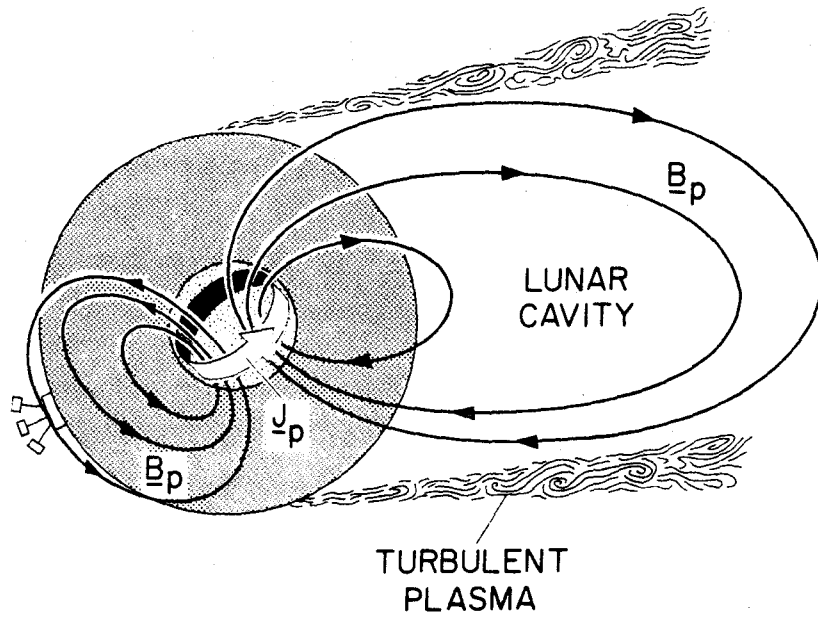
So this is really just one part of three kinds of data regarding the permanent magnetism problem on the moon. It's very likely that it has got lots of tufts of field at various points on it. The rocks are magnetized. And at one point we see a very specific measurement. And I think in the next two or three years this sort of information is going to become of critical importance in helping to assess the overall evolution in the first billion years of the earth-moon system.

Could I have the next slide, please.

(Slide) Figure 7

This now is a very schematized diagram of what we try to do with the other kind of problem -- namely, the

# LUNAR INTERACTION WITH SOLAR WIND



induction of currents in the interior of the moon. I'll assume you know what eddy currents are or, as Dr. Dyal called them, transformer action, that if you have a variable magnetic field in the presence of a conductor that the conductor will have currents generated in it. That is in fact how a transformer works. And that these currents themselves will produce a magnetic field. And what one measures is the magnetic field that is doing the driving. We call that the forcing function by Explorer 35 which is sufficiently far from the moon so that it is not affected by the moon's fields that we are inducing.

And so we measure, in effect, the baseline solar wind magnetic field. We do this when we are in the solar wind, not in the tail.

And what happens is, of course, that you induce currents in the moon, and there is a kind of magnet dipole, there is a magnetic field now in the moon, and one is interested in measuring the relationship between this induced field and the one that is doing the driving. And from doing that and spending a few thousand hours with a computer and things of that sort, one finds a profile of the electrical conductivity in the interior.

We find that the conductivity is variable, and for rocky material the electrical conductivity is most dependent upon its temperature. Also there is a strong dependence upon the chemical composition.

The two kinds of waves that are used basically that we see in Explorer 35 are either pulses like the one that Dr. Dyal showed you-- One has a step function, and then when one looks at the surface of the moon it doesn't die away very rapidly, and the reason it doesn't die away is there is some electrical resistance, and it takes some time.

The other kind of wave we look at we call a harmonic wave. It's a sine wave. And really the solar wind is filled with both of these and there is a kind of distribution of the harmonic waves of all periods, all frequencies, and we can look at those over hours and we get a spectrum, what we call a spectrum of the waves here. We compare that spectrum to the spectrum on the surface,

and the one at the surface is amplified, and, in fact, it's amplified in the most extreme cases by as much as a factor of 5, which is astounding, which is due to the fact that the field that you make on the moon is forced back into the moon by the solar wind pressure, just the mechanical pressure of the solar wind, and that field, most of it, is in a thin layer.

And the reason it's in a thin layer in the crust is that in the deep interior the conductivity is too high. In the crust it's low, and that's where the field lines can be forced into, and so you get a very large amplification.

I realize those comments were made rather rapidly. Time doesn't permit me to go into them in any more detail.

(Slide) Figure 8

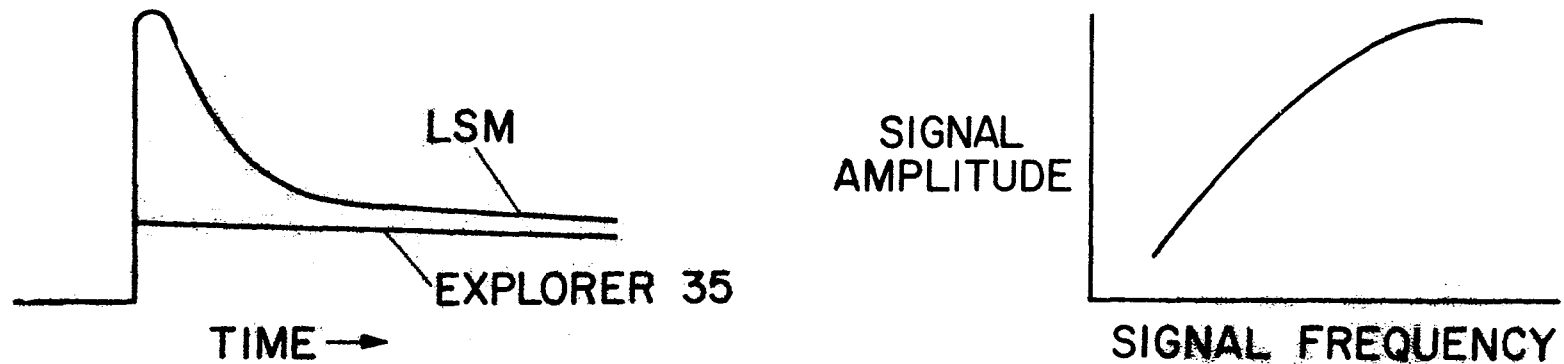
This is again schematized. This is a very artistic view of the pulse in the solar wind and the very large amplification one gets at the surface of the moon due to the large induction, to the large electrical conductivity and the field lines being packed in, contained in the crust of the moon, indicating the very substantial gradient in the electrical conductivity as we go on in. Five times amplification in pulses.

The lunar electrical conductivity increases by a factor of about one million in going from the surface to a depth of about 200 kilometers.

Thirdly, the probable cause of this is a rise in the temperature of the moon with depth. And in this gradient region in the outer crust of the moon in the lithosphere it is estimated the temperature rises by 2, perhaps 3 degrees per kilometer.

The interior temperature of the moon-- We don't know quite that we're right at the core yet, at the center, but the present evidence, which should be out in another week or so, does already suggest one is dealing with a moon whose core temperature is some 800 to 1,000 degrees Centigrade. It's conceivable it's somewhat higher, but

## LUNAR RESPONSE TO SOLAR WIND SIGNALS



- INTERPLANETARY SIGNALS AMPLIFIED UP TO FIVE TIMES
- LUNAR ELECTRICAL CONDUCTIVITY INCREASES BY FACTOR  $\sim 1$  MILLION FROM SURFACE TO DEPTH OF  $\sim 200$  km
- PROBABLE CAUSE IS RISE IN TEMPERATURE WITH DEPTH
- INTERIOR TEMPERATURE  $800^{\circ}$ – $1000^{\circ}$  C; MAYBE HIGHER

that's the present estimate.

The kind of signals that you see, which you will see in more detail on the next slide from the harmonics -- that is, from the sine waves -- have a characteristic "S" shape. As the frequency goes up the signal amplitude goes up. The "S" shape isn't here, but it really exists.

(Slide) Figure 9

I didn't want to make this presentation without showing actually some data. I apologize for the complexity of it, but this does represent substantially a year's effort in computing, using data taken from the first month, the first lunation of the LSM.

And what you see here in this rather complicated presentation is the amplification I mentioned -- that is, how many times bigger the signal is on the surface than it is at Explorer 35 plotted against the frequency. And you see that the response is going up.

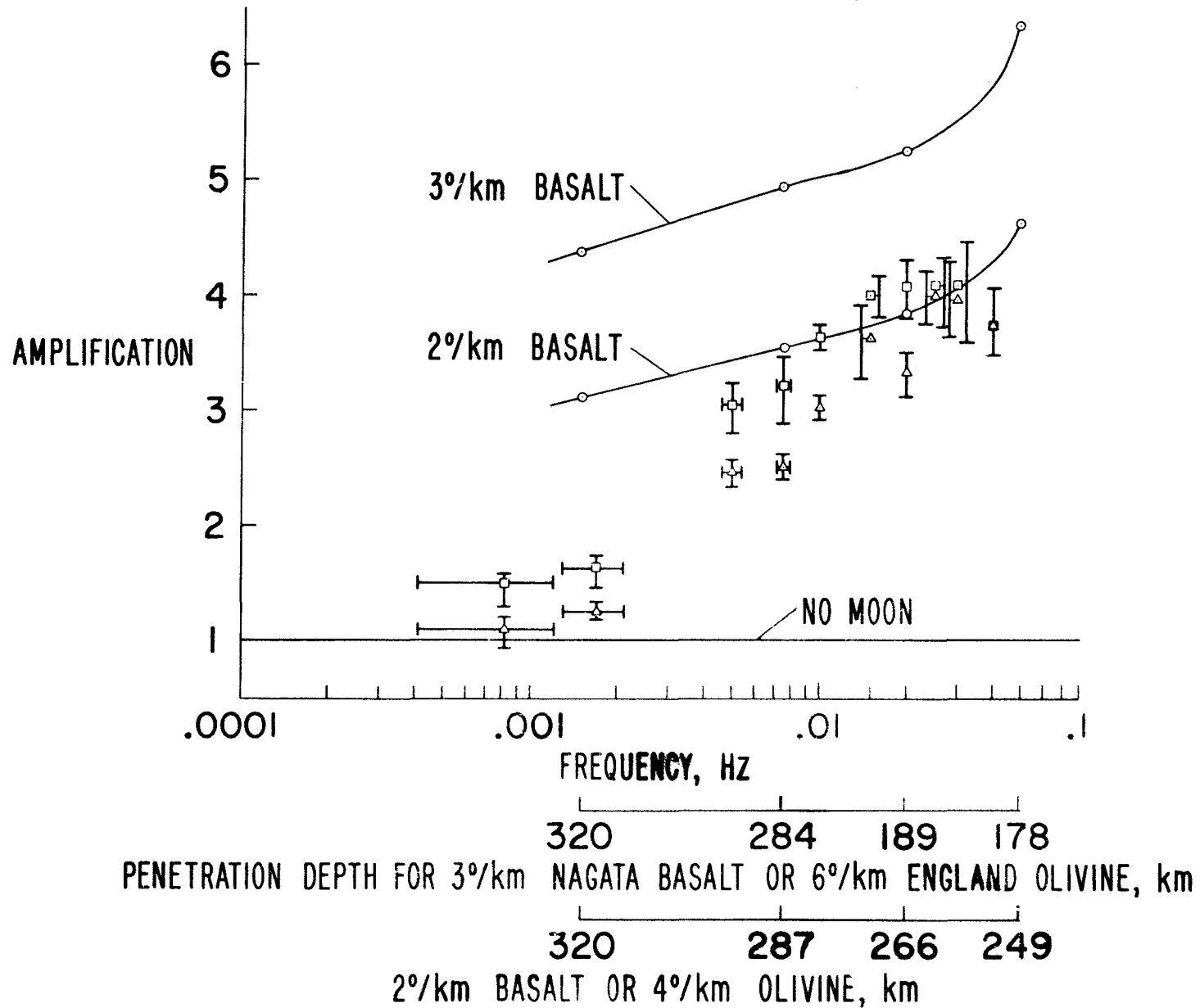
The reason for the two sets of curves here is that one is looking at two kinds of amplification really. There's the amplification in the east-west direction of the moon, local east-west, and then compass north-south. And they are different.

The first thing is that we can make a theoretical model of the moon using a 2-degrees-per-kilometer change in the temperature in the crust where we know that the change is about linear with depth, or a 3-degree, and we use a basalt from Apollo 11 which has been measured by Nagata. And this is what we should see as we go on into the moon if in fact the model behaved in a simple way where the temperature just kept going up, which is clearly not true.

This is the case if there weren't a moon at all. Amplification of 1. The signal would be the same as Explorer 35 and LSM.

These are the depths of penetration into the moon for different cases. I don't want to dwell on these because I don't think they are correct as we found after we made the slide up. In fact, the response is dropping off

# LUNAR TRANSFER FUNCTION



in the "S"-shaped curve. And it's likely here instead of looking in from about 300 kilometers we are really looking in from perhaps as much as 1,000 or more kilometers. We might be conceivably looking in within 500 kilometers of the center of the moon according to our present estimate.

That means we have looked through something like 95 percent of the material of the moon already.

The other thing I want to mention here that is extremely puzzling but very interesting-- We're not sure of it. It may be artifact. But there doesn't seem any explanation we can come up with so far that says it's that. And that is these two curves being different, which says that the amplification in one direction is different than the other.

That says if this is a real effect that the moon is electrically elliptical, it's oval electrically in the deep interior, because the differences are within the errors when we're out in the outer part of the moon, and the differences are quite significant, as high as 50 percent in this case here, when one is very deep.

Could I have the next slide, please.

(Slide) Figure 10

This is the last slide now which sort of wraps up what I have said.

A tentative model:

Likely a primordial dynamo, a very early dynamo, which means a hot core and a spinning moon, spinning at a reasonable rate.

There is, of course, this other possibility there was a close approach.

It's possible that the hot core is not consistent with the third item.

Presently 800 to 1000 degrees C. This we're not sure of yet.



## TENTATIVE MODEL



- PRIMORDIAL DYNAMO
- HOT CORE AND SPIN
- PRESENTLY  $800^{\circ} - 1000^{\circ} \text{ C}$   
AT DEPTH OF  $\sim 500 \text{ km}$   
OR MORE
- BASALT LIKE LITHOSPHERE, PERIDOTITE  
CORE
- HEAT FLUX  $1/6 - 1/3$  OF EARTH
- UNEXPLAINED ELECTRICAL  
APPARENT "OUT-OF-ROUNDNESS" BELOW  
APPROXIMATELY  $250 \text{ km}$

And we think the depth for these numbers is really more than 500 kilometers, probably more like 1,000.

We think that the best fit to our data so far is the outer two -- perhaps two hundred kilometers or so is primarily basalt-like. Electrical conductivity matches basalt composition. And then, of course, the moon cannot be basaltic as pointed out by Ringwood, because when you go deep you get material squeeze and there is sudden transition from basalt to another at density 3.7 and the moon doesn't have that great density.

We know there has to be a transition, likely something like a peridotite.

We can measure the heat flux with this experiment. We find that the heat flux is somewhere in the range very roughly of about two-tenths to three-tenths of a micro-calorie per square centimeter per second. And to give you an idea how this compares to the earth, the heat flux on the earth in regions that are not pathological varies from about 1 to 2 microcalories per square centimeter/second, and so the heat flux is of the order of a sixth to a third that of the earth.

We have this unexplained electrically apparent "out of roundness" below approximately 250 kilometers. We think it is not an instrument artifact because we don't see it at the higher frequencies. We should see it at all frequencies. So it is very frequency-dependent. It's completely unexplained at the moment but interestingly puzzling.

PETRONE: Thank you, Dr. Sonett.

Now, I asked Dr. Frank Press, who is Chairman of the Lunar Panel of the NASA Lunar and Planetary Missions Board to try to pull together the essence of the presentations we have seen here this morning, knowing it represents data back from just one point on the moon, but to correlate it and try to interpret it for us and tell us what it means in terms of a full understanding of the moon.

Dr. Press.

PRESS: My job is to summarize the ALSEP experiment, to place it in its proper scientific perspective, and to try to integrate what you have just heard.

The basic proposition involved in lunar and planetary exploration is to understand how the planets evolved from the original cloud of dust and gas and clumps of matter to the protoplanets which then accreted to form the final planets as we know them, and then each planet separately followed its own evolution over billions of years to reach the present stage, the present environment that we now know.

On earth this is a poorly understood process. We can guess that maybe 5 billion years ago we had the final accreted planet. Some of us guess that it accreted cold, and then after the first billion years it heated up perhaps due to radioactivity, and the iron catastrophe occurred where iron melted out, and that catastrophe essentially remelted the whole of the earth and you had that first stage of differentiation where you formed the molten iron core and the ferromagnesium silicate mantle.

That means that the first billion years of earth history was lost. When the earth was melted after one billion years, you lost all traces of that first beginning episode.

About three billion years ago the continents were formed. The mineral deposits began to evolve on the continents. And about a billion-plus years ago life by logical evolution started and we come right down to today in the modern environment.

The modern environment of the earth has one important characteristic which we see all around us as evidenced in the fact that we have continents and mountains. The continents are now known to drift. The ocean basins are now known to be ephemeral. They open up and they close. And so on.

The outer layers of the earth, in other words, are highly dynamic. They are mobile. And I'm going to contrast this with what we know on the moon.

Now, why did the earth follow this course and the moon apparently followed another course? Is it because of its size? Is it because of its beginning chemistry? The presence of certain trace elements? Radioactive elements? The presence or absence of water? Is it because of the distance from the sun? Is it the initial temperature?

No matter how much we study the earth from the earth, we only end up with a description of what happened rather than an explanation. And it takes the exploration of other planets to provide that deep understanding which is basic to planetary processes -- not only what is happening but why did it happen that way? Why are these mineral deposits here? At the present the way we prospect for minerals is go out and take our chances and look for them. We might use electronic methods, but it's still a "hunt and pick" method. There is no theory for why these deposits are where they are.

Now, how does ALSEP contribute to the science of comparative planetology? What is it? It's an automated observatory monitoring physical processes in the lunar environment through a series of complicated experiments which you have heard about. These experiments were all designed based upon our earth experience. That is the only way we know how to go.

But in some ways, from what we have seen, both the results and the methods used to interpret them, these results and these methods have never been used on the earth before. Some of these experiments use the moon as a platform to monitor solar processes, and others deal with the interior of the moon. And I'd like to concentrate on these last ones, particularly the rocks that are brought back and their analysis, the magnetometer, the seismic detector, the moment of inertia of the moon as we have most recently measured it, the shape of the moon, the gravity situation, the famous mass concentrations.

Each has led to basic and in most cases unexpected results, and the joint interpretation of these will make the big impact that we all expect.

Quickly to recall for you the important things about the rocks, they are very old. Rocks are found on the

moon that are older than any found on the earth. To unravel the first billion years of history on the earth which is not available to us any more because of that melting process, we probably will have to go to the moon.

The fact that you have old rocks on the moon indicates that these processes, dynamic processes, are very, very sluggish. The outerlayers of the moon are relatively stable compared to those on the earth. Over 80 percent of the earth you cannot find a rock that is older than a hundred million years.

Why? Because the rocks are recycled. They are formed, they are remelted, they are remolded, they go back down, and come back out many, many times. This process apparently is not occurring on the moon.

There is no trace of water on the moon, either free water or in any of the minerals. Absolutely none. I think this is very important in terms of understanding the difference between the earth and the moon.

The moon has an unequilibrium shape. It supports large masses which have their corresponding anomalies, all of this indicating great strength in the outer layers of the moon.

Now, remember this as we go to the next experiment, the magnetometer, which you have just heard about. From what we have just heard, the temperature at a depth of 200 kilometers in the moon is about the same as it is on the average 30 kilometers depth on the earth. In other words, the earth gets hotter more rapidly than the moon does.

In fact, if those numbers that Dr. Sonett quoted turn out to be his final results, you can say that nowhere in the moon -- as long as the temperature is lower than about 1,000 degrees -- nowhere is there molten rock. And if he can go within 500 kilometers of the moon's core, then most of the moon is solid.

Contrast that to the earth where at a depth of 100 to 200 kilometers you have already reached temperatures which bring the earth to a partially molten state at this shallow depth.

The presence of water. How is that important? What water does is lower the melting point of rocks, and so the earth would melt at even lower temperature than the solid moon. And the fact that its temperature is higher gives you a more extensive partially molten region.

Now, this, of course, ties in with the seismic result. The low seismicity of the moon is a major result, and it's understandable at least in terms of what we have just said. By that I mean the fact that-- Well, let's go back to the earth for a moment. Seismicity on the earth is correlated with the fact that the earth is highly mobile, that it consists of about a dozen or so plates, rigid plates. of dimensions of thousands of miles, and where these plates jostle each other, where they rub each other, that's where you get the seismic activity. Where these plates are pushed into each other you get the mountains and the deep sea trenches. Where they are pulled apart you get the mid-ocean rifts and mountain chains.

And what drives these plates one into the other producing vulcanism and seismic activity? I believe it's the partially molten zone below these, and convective motions in this partially molten zone split the plates apart, move them into each other, and so on.

Well, the moon is frozen all the way through, or most of it. And this primary mechanism present on the earth is absent on the moon. Perhaps this explains the remarkable contrast in the ages of the rocks, in the temperatures with depth, and the absence of seismic activity.

An important result on the moon is that there is some seismic activity of a superficial kind, very, very little, but that it is correlated with tidal strains. For decades we have looked for triggering mechanisms of earthquakes, and we have studied tidal correlations with seismicity to death, and we haven't been able to find the correlation. We have now found one so strong on the moon that you don't really need fancy statistical techniques to state that it exists in a confident way.

I think this is going to trigger us to go back and study the earthquake triggering problem in a more subtle way now that we think we know at one place in the solar system moonquakes or quakes can be triggered by

external process. Let's go back and see if that occurs on the earth.

The reverberation, the remarkable reverberation, of seismic waves on the moon, indicating a very high elastic quality factor. You might say why is it important whether or not seismic waves are absorbed on the moon and not absorbed on the earth? The elastic quality factor, the absorptility of the moon is also correlated with strength of the rocks, and if we can understand why the lunar rocks are remarkably elastic, they don't absorb the seismic waves in contrast to the earth, we will learn something about the strength differences on the moon.

It may be that water is again the important element. The absence of gases and water on the moon may, as has been suggested, wherever there is a fracture on the moon and rocks touch-- That contact may be a welded contact which is only present in a lunar vacuum in the absence of gases and liquids.

On the earth that doesn't occur. Water is abundant. And so where cracks are formed, motion can occur absorbing seismic waves and also producing the "stick slip" mechanism that creates earthquakes.

So all of these observations seem to fit into a recognizable pattern. But I would like to stress this: When we designed the Apollo program, at least the lunar exploration part or the scientific exploration part, we didn't have in mind a single ALSEP. We knew in advance from certain experience that you need a network of monitoring stations on the moon. You need synoptic coverage.

We are fortunate in how much we have learned from that one station. But really all that we have right now are the pieces of a jigsaw puzzle. We don't really see the final pattern.

It's like the state of exploration of the oceans as it was back five or ten years ago. After two decades of exploration of the sea floor we finally and very quickly saw the way. All of the things we have been observing fit together in a single, all-inclusive theory on how everything fits into shape. And we now understand the

basics of geology for the first time in the whole history of the subject.

We are not at that point on the moon. We won't be at that point from a single ALSEP. So we do have the danger of stopping prematurely before this synthesis can be made.

ALSEP, therefore, is the first probe, the first element, of an array, and that's the way it should be considered.

So the moon is cold and thick, has a thick lithosphere, a strong lithosphere, no partial melting, no motions of the melt to split this plate apart to produce vulcanism, produce the mobility that we see on the earth. I think this is one important result. And I have mentioned the connection with water, and so on.

So we see the way the moon and the earth have followed different paths in their evolution, why the temperatures were different, why one planet has water, the other doesn't. That's the kind of question we want to address ourselves to in the continued exploration of the moon.

We have demonstrated that the combination of an automated observatory together with sample return is the most powerful combination. And apparently the Russians by sample return and automation on the surface of the moon have reached the same conclusion.

Why should we return to the moon? Well, I have mentioned the scientific reasons. And I think you have all heard the arguments of national prestige, of employment of people in useful pursuits, of diffusing the arms race, of international cooperation, of the practical fallout. And these are all valid.

But -- maybe it is naive for me to say this in this very tough and cynical time -- but to me the exploration of the moon is part of the great intellectual quest of man to explore the cosmos, a drive that he has had since the beginning of time, not only to protect and enrich himself but essentially to satisfy this basic desire to



probe the unknown, and it would be a pity if the exigencies of the moment deflect us from the very important exploration, perhaps the most important exploration in the history of man.

ALLAWAY: We want to give you opportunity to ask questions of the people who have reported this morning. We will very quickly get them on the stage. We are running into the lunch hour but I know you do want to talk to them briefly.

We have here Mr. Carpenter from AEC who can answer questions on the generator.

QUESTION: Dr. Press, why didn't the moon melt with compression like the earth? That's bothering me in your explanation.

PRESS: I didn't get the first part. Why didn't -- ?

QUESTION: Why didn't the moon, you know, melt after compression -- that is, you know, accreting, coming together very solidly, like the earth did? Is it because it's a smaller body or not? That has bothered me.

PRESS: Right. The reason a planet would melt after it has accreted is, one, the temperature rise due to the energy conversion of mechanical energy, energy of impact, into heat, the self-compression, the adiabatic compression, of the planet and radiogenic heat generated by the radioactive materials.

The moon might have less radioactivity. The self-compression would certainly be less than on the earth because the moon is a smaller planet. Both of these effects could easily prevent the moon from melting extensively as did the earth.

Remember that the fact that there are igneous rocks on the surface of the moon does imply at one stage way, way back the moon did melt to a certain extent.

QUESTION: I guess Dr. Press could possibly handle this. John O'Keefe out at Goddard is delivering a paper up in New York on Friday in which he contends the

moon split off from the earth after the earth's core was formed and reaches this conclusion from Apollo 11 tests which show a deficiency of nickel in the moon.

Now, is there anything in the results of Apollo 11 or 12 that you know of that would either tend to uphold or conflict with O'Keefe's theory?

PRESS: Well, you know, scientists have different styles, and John's style is to think in terms of these large-scale hypotheses based upon preliminary results. That's not my style.

He may be right, but I certainly wouldn't be willing to say that at this stage of exploration.

QUESTION: I have two questions from Dr. Latham. Last July I believe it was, Dr. Latham, you were down in Houston and you were puzzled by the similarity of the seismic events that you had recorded on the moon. You thought perhaps that they might in some way be correlated to the orange glow which has been spotted by astronomers for years.

No. 1, is there any correlation? And do you have any explanation for the identical events?

LATHAM: The lunar transient events that astronomers report as bright flashes or colorations that appear or even short-term obscuration of the surface and which they interpret as gases escaping in puffs presumably from volcanic areas also happen at monthly cycles and at times of perigee.

And so we were excited at the possibility that our repeating moonquakes which also occur at perigee could be related in some way. That is, both may be triggered by the strain within the moon induced by the gravitational attraction between the earth and the moon.

So far we have had three reports of lunar transient events from Fra Mauro region, and none of them corresponded to a time at which a seismic event was recorded.

And so the answer is negative. No correlation thus far. And only in the statistics is there correlation.

And we still hope that we may eventually see an event reported by astronomers and that we also see signal at that time.

Now, the repeating events or these very identical events are the moonquakes. So the explanation that we are offering here is that these very repetitive signals that happen at monthly intervals are indeed moonquakes generated perhaps by slippage along fractures in the outer shell of the moon at at least nine different places in the region of the Apollo 12 station.

I mentioned the analogy with the San Andreas fault where earthquakes are generated by slippage along that fault. In that case, however, we are seeing large-scale displacement. That is, scientists believe that the total displacement one side of the fault to the other over the interval in which that fault has been present may be hundreds of miles with the Pacific Ocean side going northward relative to the continent, whereas on the moon we see no evidence at all of these large-scale horizontal displacements.

If a real (trans-ex) of a crater goes right through the crater, the walls are still aligned on either side. So my hunch is we are dealing with vertical motion. One side of the fault drops down relative to the other side.

And we hope -- this may not be expressed at the surface -- that is, it may be occurring at sufficient depth that the rubble, the regolith covers it up -- but if you're lucky and can see these scarps in the closeup photography, we may be able to estimate how long this process has been going on and maybe what caused it to happen.

QUESTION: Another one. Dr. Latham, would this explain the identical signals that you said you were puzzled by? Vertical movement would give you event after event with identical seismic signals? You said you couldn't account for this.

LATHAM: Yes, the feeling that I tried to give you then I still feel. That is, you can postulate a repetitive process where the slippage occurs at exactly the

same point and exactly the same way month after month, but it is very, very rare indeed that on earth we see signals from the same region with such identical character happening over large intervals of time, and so I still feel as I did then that this is a very, very rare circumstance on earth but appears to be possible in the very rigid outer shelf of the moon.

QUESTION: For Dr. Sonett and perhaps also Dr. Press. What correlation do you see, given this moon with the temperature below a thousand degrees, between that temperature and the transient events?

PRESS: Are you speaking of the transient seismic events?

QUESTION: The gas escapes, and so forth, that have been postulated to come from volcanic activity.

PRESS: Well, I agree with Dr. Latham's interpretation that these transient events do indicate some residual strain that is being released apparently triggered by the tides. These are extremely small events. He has a super-sensitive seismic system. So compared to the seismic activity on the earth you might say that the moon is essentially aseismic in terms of the large-scale tectonic earthquakes we have on the earth.

So I would say that what impresses me is the low temperature of the moon and the absence of large-scale seismicity.

QUESTION: Perhaps I didn't make myself clear. Assuming that cold moon picture, how would you explain the generation and escape of gas? Would there be room for some volcanic generation of that gas? Or what would generate it?

PRESS: Well, perhaps a number of people could answer this, but my guess would be that it's quite feasible to have residual gas entrapped from very early processes. It's quite feasible to have gas entrapped, radiogenic gas, that gets locked up into cracks and crevices.

It may be that impacts at some time in the past produced local melting and there are some puddles of still molten material some kilometers beneath the surface, and

so on.

QUESTION: I have a couple of questions. I might as well get them off my mind while I have the mike. One of them is for Dr. Sonett with respect to this 35-gamma field which you say is steady and localized within 200 meters to 200 kilometers of where the ALSEP package is. Does this mean to say that this is not a global field or that there may be many localized magnetic fields around? Would you explain that?

SONETT: Well, this particular event that we see is not an event really, because it's steady. But this particular field that we see is definitely not global, and we know that from when Explorer 35 flies over the site it doesn't detect anything. So you get a bound.

Now, when you say it's somewhere between two limits, what you have to do is make a model, and there are many, many possibilities. Obviously the most likely one is magnetized lava or basalt.

When I quoted those numbers for distance, I imagined that the field was localized to a point source lying on the surface of the moon. It's very idealized.

And the last point, about other places on the moon that might have such magnetism, there is some reasonably strong evidence that there is quite a bit at isolated spots and much more on the back side and generally limited to the highlands rather than the mare region.

That comes from a very recent examination of about two years of Explorer 35 data.

QUESTION: The other question-- I don't know who it would be for, but it relates to the frequency of meteorite hits, that if you get about once every month a meteorite the size of a grapefruit or a little larger hitting the moon, what sort of crater would each of those create?

SONETT: You're looking at me, but I suspect there are other people here better able to answer it.

LATHAM: We estimate the diameters of those

craters would be of the order of 10 to 20 meters perhaps, so we should be able to see a few of the largest.

QUESTION: This is for Dr. Freeman. In your gas bubble, where is that gas coming from? Is that radiogenic gas coming from the moon from the impact of the S-IVB?

And, further, the naturally occurring ion clouds, where are they coming from? Or give me a guess or something.

FREEMAN: In the case of the S-IVB impact event there are several possible sources for the gas. Of course, there is believed to be some residual fuel and oxidizer remaining in the S-IVB stage itself. I don't think there is any good data on the exact quantity, although it is, generally speaking, a very small fraction of the S-IVB stage total mass.

A much more likely bet I think is that what we are seeing is the liberation of surface gas. We know that the lunar fines and the rock samples are extremely heavily loaded with things like helium particularly and argon and krypton, and my best guess at the moment is that we are probably seeing largely liberated surface gas.

We're not able to give a precise answer to the mass constituency in this impact event for the simple reason that the fluxes are changing so rapidly during the sudden burst that the flux change is fast compared with the time required to do a complete mass spectrum.

In other words, we sweep through a mass spectrum slowly compared with the time rate of change of the flux. And so all we have really is sort of a broad sphere of mass peaks and we can only say in general it appears that the masses that are present lie predominantly in the mass range from about 10 to 80 atomic mass units. And I wouldn't want to say where the actual peaks are because of this time resolution problem.

As to the second question, the gas liberated from the natural ion clouds or the gas represented in natural ion clouds, again we have a rather broad smear of spectra indicated from approximately 18 to 50 atomic mass units,

and we haven't been able to determine with precision yet what specific elements are represented. My guess is that we are seeing the effects of sporadic outgassing from the surface, possibly volcanic activity, this kind of thing. However, again, that must remain a relatively tentative estimate.

ALLAWAY: Thank you, gentlemen. I believe there are no more questions. We expect to have a transcript about Monday or Tuesday.

(Whereupon, at 12:20 p.m., the news conference was concluded.)

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